13 OCT 1980

NOTES FOR FORECASTERS—GIBRALTAR

by

W.McKay

INVESTIGATIONS DIVISION TECHNICAL NOTE No. 19

Met. O. 9.
October 1980

Note: Permission to quote from this unpublished note should be obtained from AD Met.O(SI), Meteorological Office, London Road, Bracknell, Berkshire RG12 2SZ.

ORGS UKMO I

National Meteorological Library
FitzRoy Road, Exeter, Devon. EX1 3PB

Notes for Forecasters - Gibraltar

Table of Contents

Para

1 - Introduction
2 - Local Terminology

Sect. A - WINDS

3 - General
4 - The Alicante-Casablanca Surface Pressure Difference
5 - Surface Winds - Climatology
6 - Easterly Situations
7 - Westerly Situations
8 - Features of Easterly Winds
9 - Features of Westerly Winds
10 - Diurnal Variation of Surface Winds
11 - Diurnal Variation of Winds at Rock Top level
12 - Sea Breezes
13 - Variation of Wind Direction Along the Runway
14 - Differences in Direction between Surface and Low Level Flows
15 - Forecasting Rules for Surface Winds
16 - Turbulence

Sect.B - RAINFALL

17 - General
18 - Climatology
19 - Winter Rainfall
20 - Summer Rainfall
21 - Diurnal Variation of Rainfall
22 - Forecasting Rules for Rainfall

Sect. C - VISIBILITY

23 - General
24 - Fog
25 - Percentage Frequencies

Sect. D - CLOUD

26 - Cloud Types
27 - Cloud Bases
28 - Diurnal Variation of Cloud Base and Amount

3 8078 0001 8516 7

List of Diagrams

Fig.
1. - Topography and Rainfall - Southern Iberia and NW Africa.
2. - Straits of Gibraltar showing depths in fathoms.
3. - Times of Wind Changes - North Front.
4. - Time lag in Change of Wind at North Front after change of Ali-Cas PD.
5. - Ali-Cas PD and Wind Speeds at North Front.
6. - Wind Rose - Annual.
7. - " " - Summer.
8. - " " - Winter.
9a. - Percentage Frequencies of Westerlies, Easterlies and Calms at Gibraltar.
9b. - " " of Wind Directions at Gibraltar.
10-25. - Easterly Situations.
26. - Strong Easterlies west of the Straits.
27-30.- Westerly Situations.
31-34.- Change from Easterlies to Strong Westerlies and back to Easterlies.
35. - Sea Breeze circulation in the vicinity of Gibraltar.
36. - Location of Anemometers - Gibraltar.
37. - Difference in direction between Centre and East and West Anemometers.
38. - " " " " " " Rock Gun Anemometer.
39. - " " " " " " 1000 ft wind.
40. - " " " " " " 2000 ft wind.
41. - Rainfall Stations and Averages - Gibraltar.
42. - Diurnal Variation of Precipitation - Annual.
43. - " " " " - Seasonal.
44. - Mean Rainfall per Rain-hour.
45. - Houseman's Rain Forecasting Diagram (a)
46. - " " " " (b)
47. - Pepperdine's Rain Forecasting Rules - Basic Criteria.
48. - " " " " - Flow Diagram.
49. - Surface Water Flow in the Vicinity of Gibraltar.
50 - SKETCH MAP - NORTH FRONT
51 - GALES IN THE ALBORAN BASIN WITH STRONG NN'LY UPPER FLOW.

Sect. E - SUNSHINE

29 - Monthly Averages and Local Variations

Sect. F - OCEANOGRAPHY

30 - Movements of Surface Waters near Gibraltar

31 - Sea Temperatures near Gibraltar

32 - Variation of Sea Surface Temperatures near Gibraltar

33 - Sea Conditions near Gibraltar

Sect. G - MISCELLANEOUS

34 - Thunderstorms

35 - Hail

36 - Snow/Slect

37- Waterspouts

Sect. H - CLIMATOLOGICAL TABLES

38 - Climatological Data - North Front 1947-1976

39(a-ℓ) - Additional Climatological Data for each Month

Appendices

A - Bibliography of published and unpublished material relating to Gibraltar

B - Some examples of synoptic situations

Tables

Ia - Percentage Frequencies of Surface Wind Direction at Gibraltar.

Ib - " " " " " Speeds " " .

Ic - " " " " " " Calm, Force 3 and below, Force 4, and Force 5 and above.

II - Analysis of Gales at Gibraltar.

III - Turbulence on Finals related to wind speed and direction.

IV - Rainfall at Various Gauges at Gibraltar.

V - Mean Monthly Surface Pressures - Gibraltar.

VI - Percentage Frequencies of Visibility at Gibraltar.

VII - Average Cloud Amount - Gibraltar

VIII- Average Number of Clear and Cloudy Days

IX - Climatological Tables - North Front.

X - Additional Climatological Data for Gibraltar

SECT.A - WINDS

3. General.

3.1 It will be readily evident from a study of Fig.I that the high mountain ranges of Southern Iberia and North Africa and the configuration of the coastlines of the Straits and Alboran Basin areas must profoundly affect wind and weather conditions in these areas. In general terms, winds in the Straits area are usually channelled either easterly or westerly depending on the pressure distribution to the east and west of the Straits. Lee troughs or lows play a very important part in the pressure distribution and cloud cover and precipitation can vary markedly over comparatively short distances in both areas.

3.2 Another important feature of the Straits and Alboran Basin is that they are the meeting and mixing areas for Atlantic and Mediterranean waters which in some seasons of the year have widely divergent temperatures both surface and subsurface.

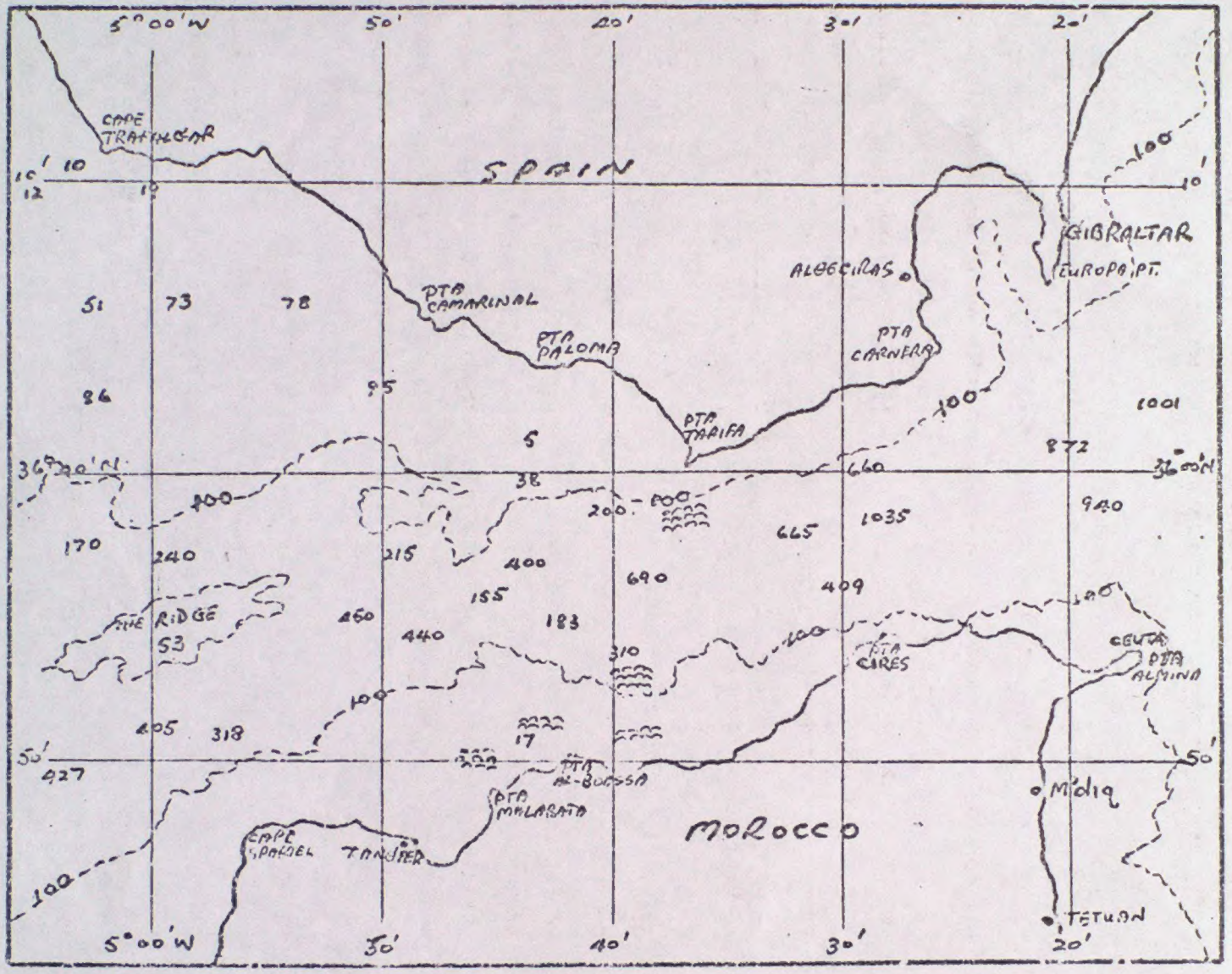
3.3 Surface waters in the Straits area are almost always east-going due to the excess of evaporation over inflow in the Mediterranean. They are however profoundly affected by wind speed and direction in addition to tidal flow and large surface temperature changes can result with changes in wind regime.

3.4 At lower depths, there is a west-going flow of cold and very saline water in the Straits. Due to the topography of the sea-bed (Fig.2) considerable upwelling of this water occurs, particularly in the western Straits.

3.5 A combination of the factors at 3.2 to 3.4 can give rise to very large gradients of sea surface temperatures which have an important bearing on the incidence of sea fogs, low stratus and precipitation in the Straits and Alboran Basin areas. More detailed information on sea surface temperatures, surface water movement and circulation in these areas can be found in Section F.

3.6 Another major influence on winds and weather at Gibraltar is the Rock itself Rising to nearly 1400 ft and orientated approximately north-south, it presents a considerable barrier to the predominantly easterly or westerly winds of the area. As a result there are considerable variations of local climate, rainfall, sunshine etc. which will be discussed later in these notes in addition to the wind eddies and turbulance which have attracted the attention of a number of investigations and resulted in three separate wind tunnel tests using a model of the Rock (Refs. 1 to 3). The local wind eddies and turbulence at Gibraltar are discussed at some length in para. 16.

FIGURE 2 - STRAITS OF GIBRALTAR SHOWING DEPTHS IN FATHOMS
(POSITIONS APPROXIMATE)



4. The Alicante-Casablanca Surface Pressure Difference (Ali-Cas) and Wind Changes at North Front

4.1 Surface and low level winds at Gibraltar and in the Straits area are almost always westerly if pressure is higher to the west of the Straits than to the east, and easterly if the opposite situation occurs. It was found during World War II that the times of change of surface winds at North Front were closely related to the times of change in the surface pressure difference between Alicante and Casablanca, and it has been the practice since that time to maintain a running graph of that difference as a forecasting aid.

4.2 However, it has been noted by several writers eg. Ward (Ref. 4) that there are preferred times for changes from westerlies to easterlies and vice versa. These preferred times were further investigated by Atherton using 1953-1967 data, and in Fig. 3 his results clearly show a marked tendency for easterlies to set in during the late morning and westerlies to set in during the evening. Various explanations have been offered for these tendencies, but it seems highly probable that the major influence is the katabatic drainage from the Algeciras and Ronda hills, which frequently overcomes light easterly gradients to produce light surface westerlies during the night at North Front which then revert to easterlies as the katabatic drainage ceases after sunrise. Supporting evidence for this is to be found in Fig. 3 - the summer changes from westerlies to easterlies occur earlier than in the winter months. With changes from easterlies to westerlies there is a tendency for these to happen earlier in the summer than in the winter if they are to occur in the afternoon period - probably as a result of the sea-breeze component - but in the evening when most changes occur, they are more likely to occur sooner in winter than in summer.

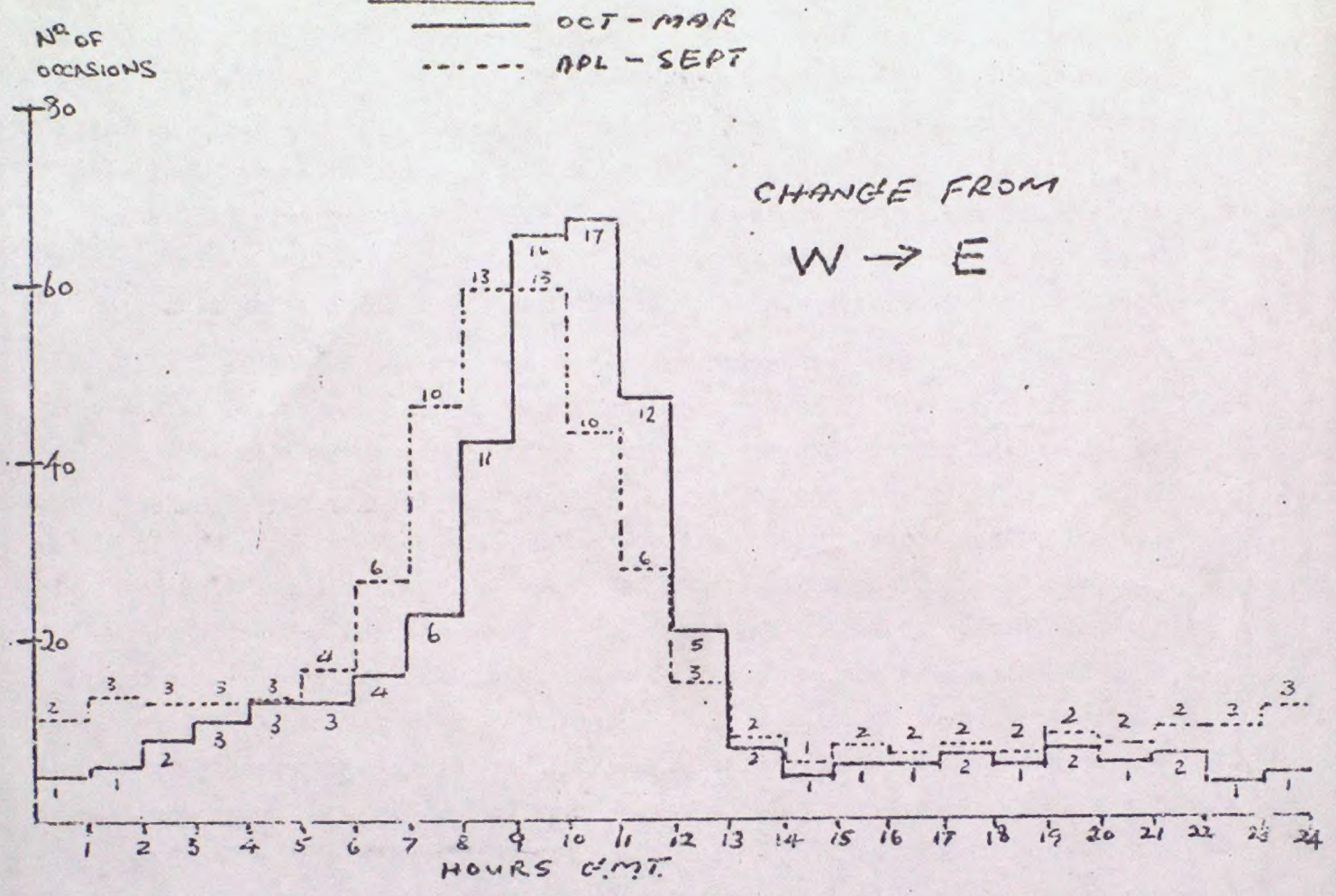
4.3 Atherton also gives average and extreme values of the time lag between changes of the Ali-Cas from westerly to easterly and vice versa and the corresponding changes in surface winds at North Front. These are shown in Fig. 4 . They clearly indicate the reluctance of easterlies to set in during the night and the westerlies to set in during the day.

4.4 It has also been long apparent that a high correlation exists between the strength of surface and low level winds at Gibraltar and the magnitude of the Ali-Cas pressure difference. From time to time various writers have suggested values of wind speeds appropriate to the magnitude of the Ali-Cas. The relationship has, however, been more fully investigated by the writer (Ref 5) and the results are given in Fig. 5 in which are given curves relating mean values of wind speed at the surface, 1000 and 2000 ft levels to the Ali-Cas

Fig:-3

TIMES OF WIND CHANGES (JAN 1953 - DEC 1967) AT N. FRONT.

DIRECTION OF WIND REMAINING FOR 3 HRS OR MORE AFTER CHANGE



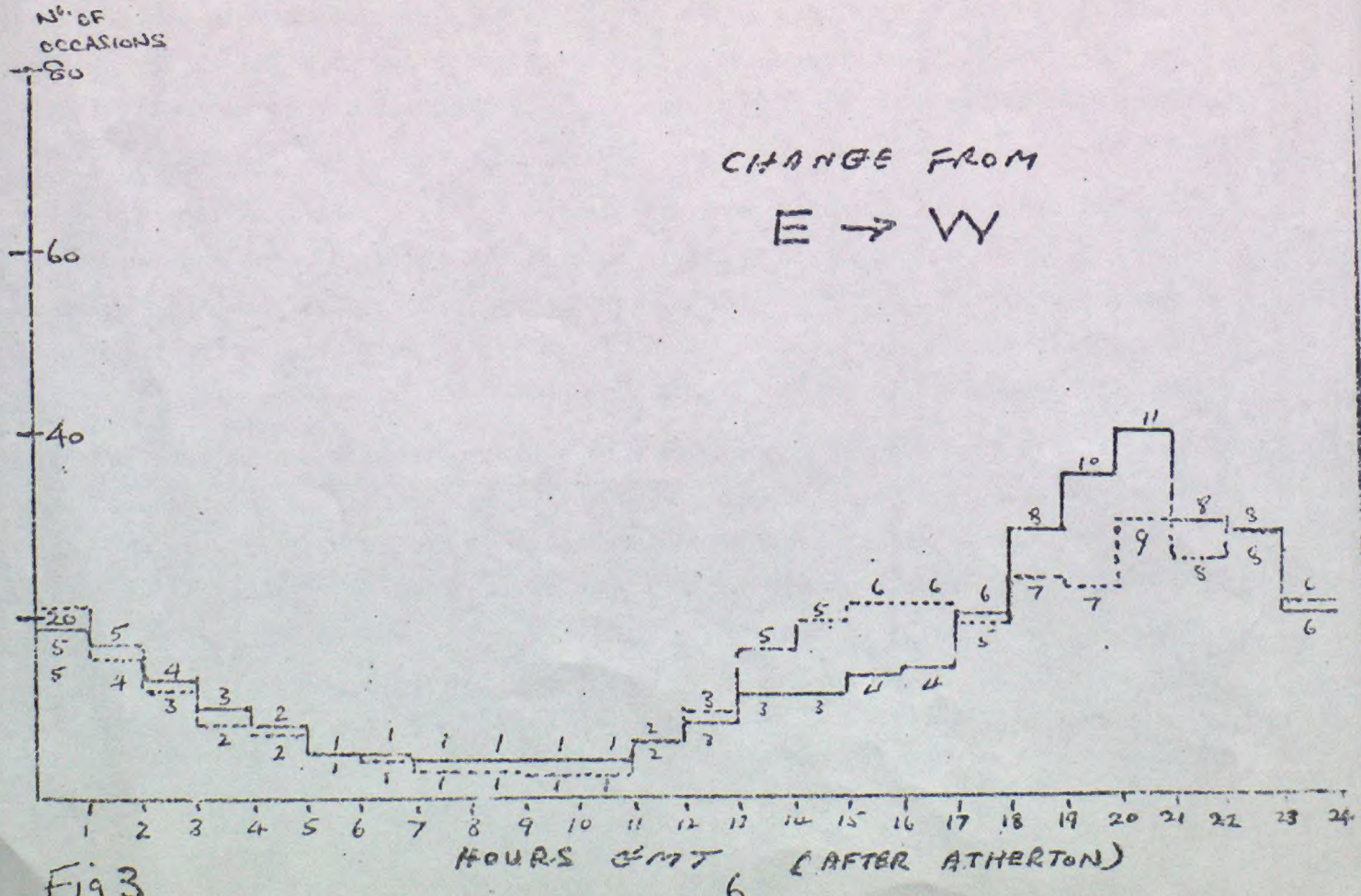
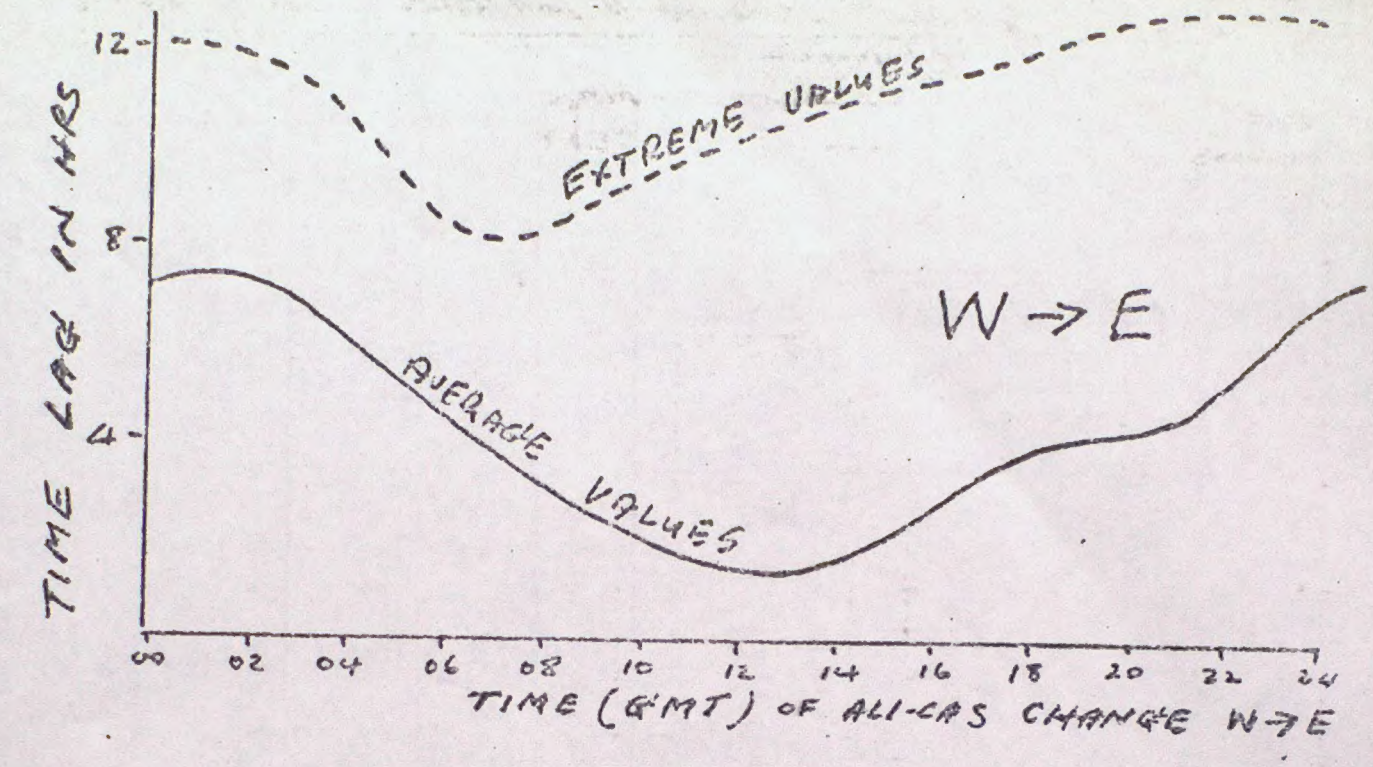


Fig 3



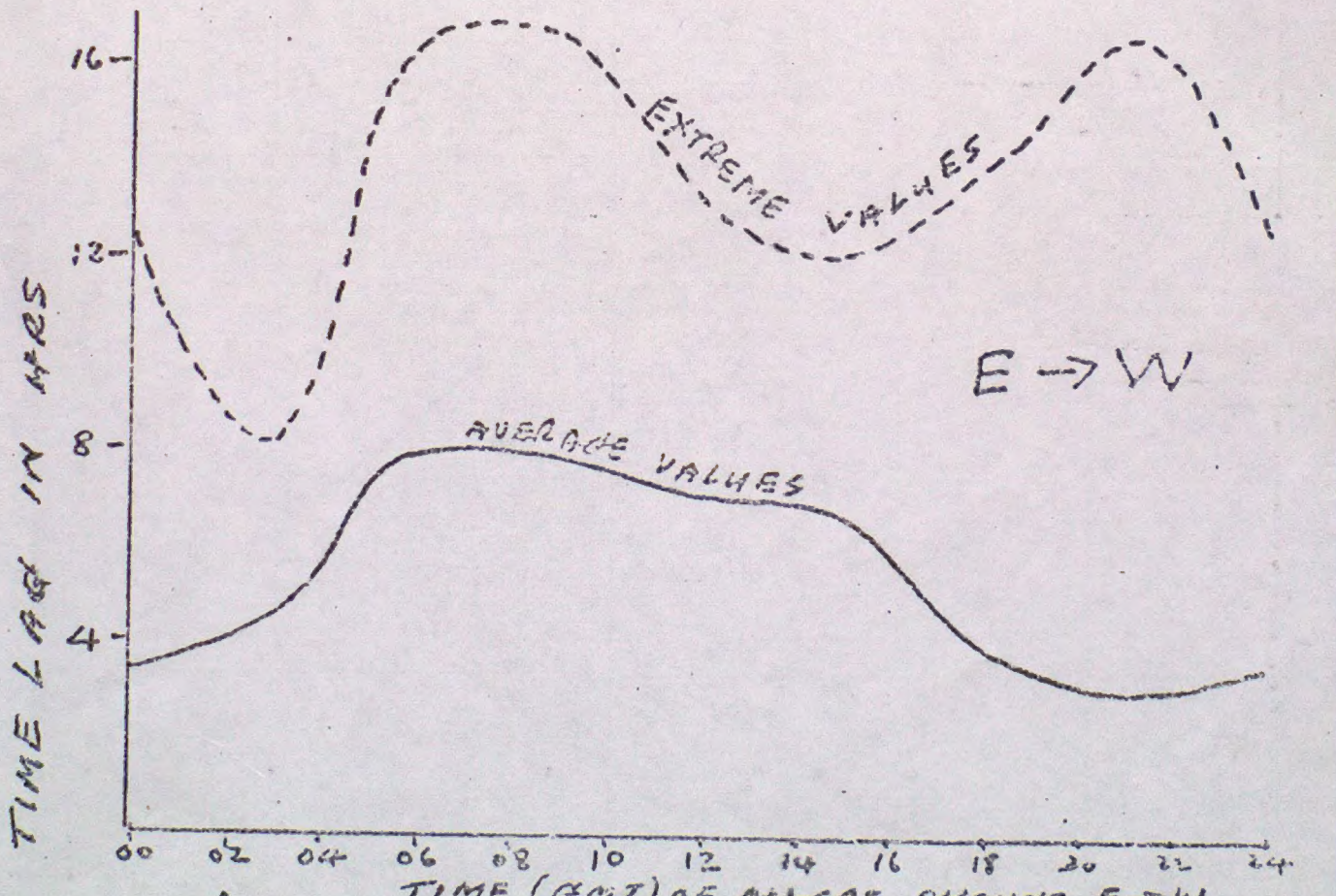
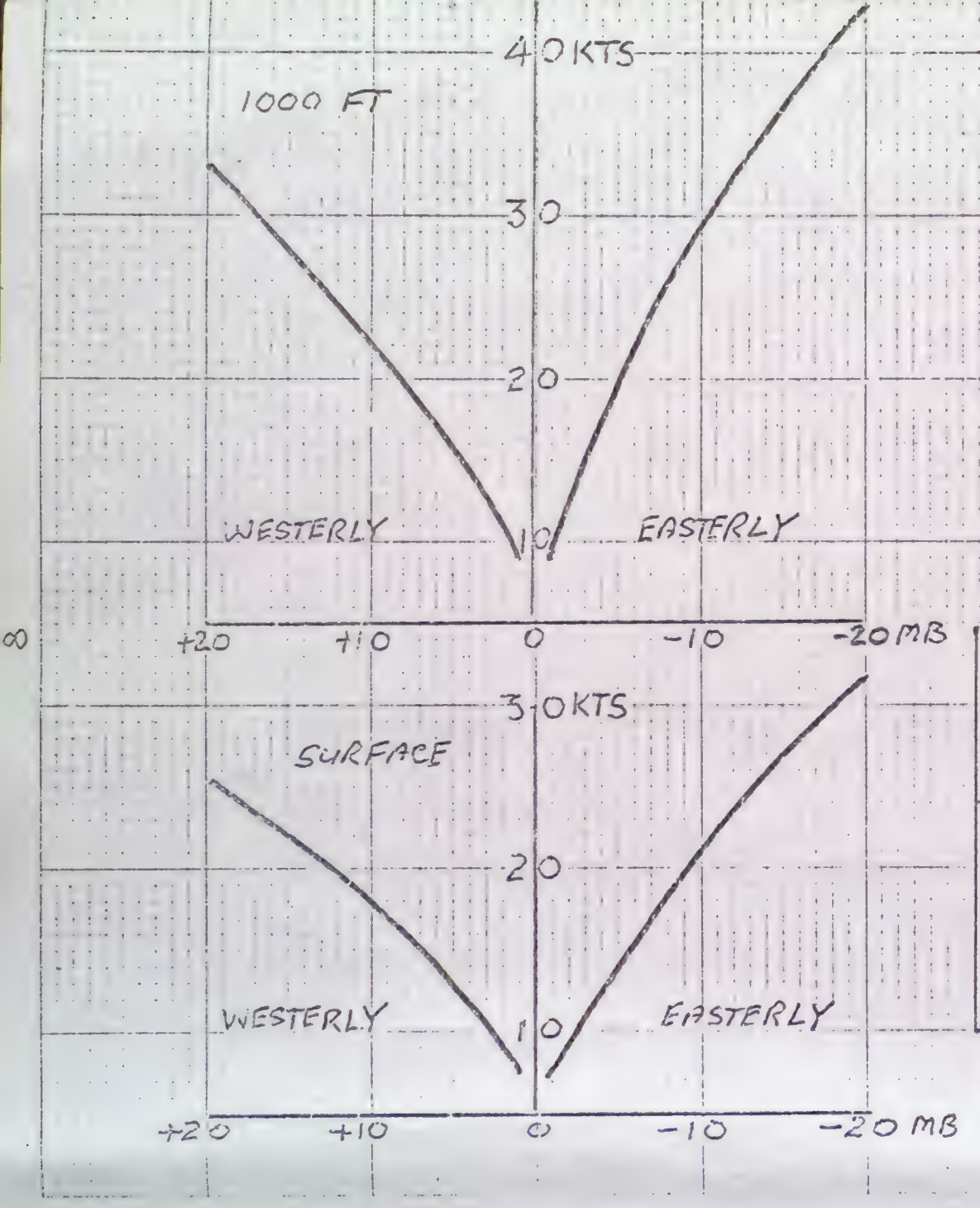
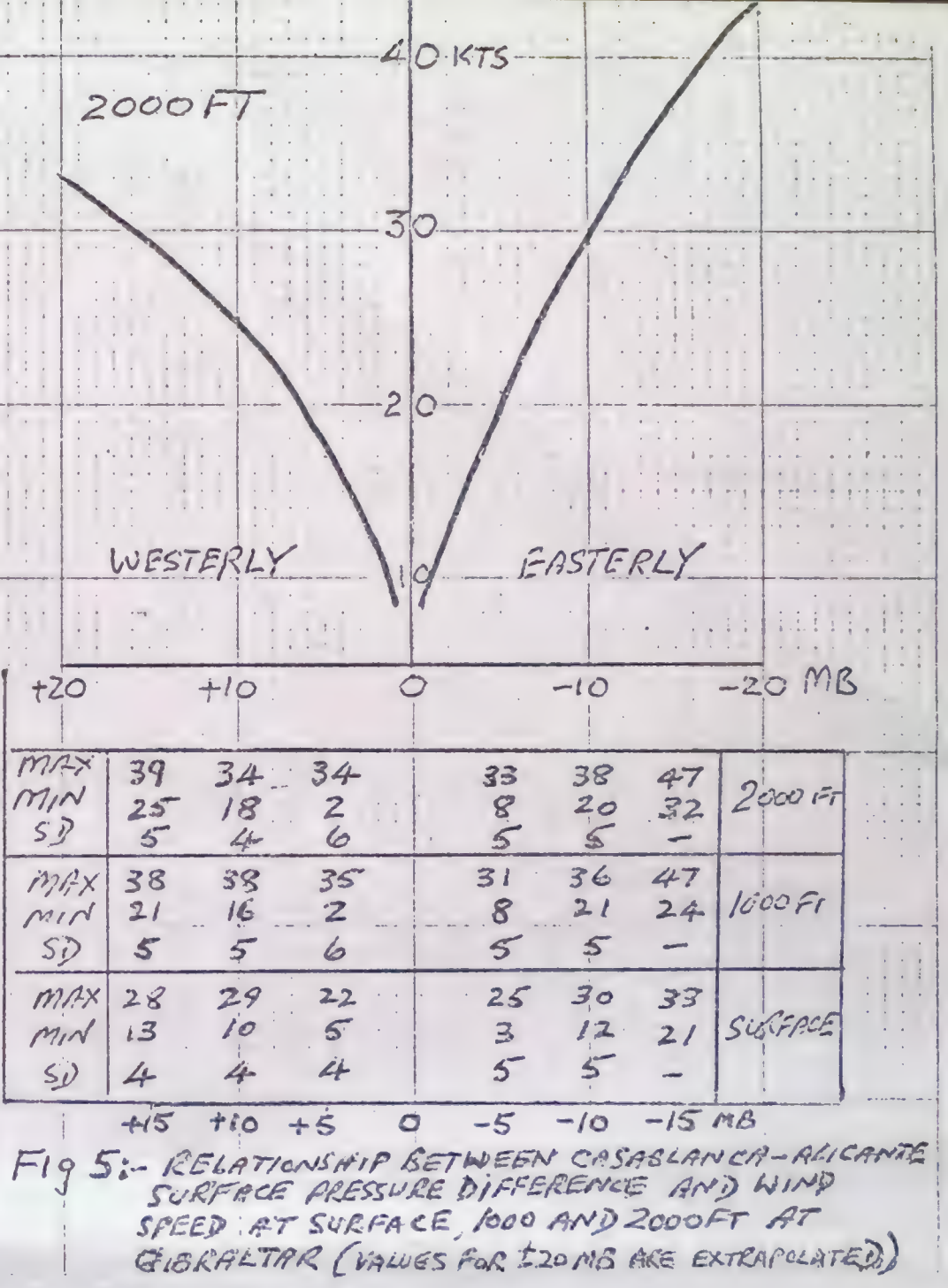


FIG 4 :- TIME LAG IN CHANGE OF SURFACE WIND AT NORTH FRONT AFTER CHANGE OF ALI-CAS. (AFTER ATHERTON)

BASED ON 1953 - 1967 DATA





MAX	39	34	34	33	38	47	2000 FT
MIN	25	18	2	8	20	32	
SD	5	4	6	5	5	–	
MAX	38	38	35	31	36	47	1000 FT
MIN	21	16	2	8	21	24	
SD	5	5	6	5	5	–	
MAX	28	29	22	25	30	33	SURFACE
MIN	13	10	5	3	12	21	
SD	4	4	4	5	5	–	

+15 +10 +5 0 -5 -10 -15 MB

Fig 5:- RELATIONSHIP BETWEEN CASABLANCA-ALICANTE SURFACE PRESSURE DIFFERENCE AND WIND SPEED AT SURFACE, 1000 AND 2000FT AT GIBRALTAR (VALUES FOR ±20 MB ARE EXTRAPOLATED)

pressure difference together with standard deviations, maximum and minimum values observed at 5 mb intervals.

4.5 There are however several points to be remembered when using Fig. 5. These are:

(a) the high correlation which exists between the magnitude of the Ali-Cas and wind speeds at all three levels tends to break down if, in the Straits or Alboran Basin areas, there are (1) small scale pressure systems eg. lee lows (2) surface fronts or (3) upper troughs. It also breaks down on days when the sea-breeze (Ref. 10) occurs.

(b) in the presence of a low level inversion and a westerly gradient, the speed at North Front is often much lower than Fig. 5 predicts. In such a case, the Rock Gun anemometer is a better guide to surface wind speeds in the Straits.

(c) with light easterly gradients (10 kts or less at the 2000 ft level) the surface wind at North Front is very frequently less than would be predicted by Fig. 5 or reversed to a light westerly due to katabatic drainage from the Algeciras and Ronda hills. In such a situation the Rock Gun anemometer usually indicates a definite easterly which may be a little stronger than predicted by the 1000 ft diagram.

(d) situations occur when the bulk of the Ali-Cas difference may lie either east or west of Gibraltar. In such circumstances, the diagrams must be used with discretion.

(e) with surface fronts approaching from the west the surface wind (usually SW'ly) at North Front is frequently considerably in excess of that predicted by the Ali-Cas. The best guide in this case are the winds experienced at Rota, Jerez, or Seville as the fronts approach these stations.

(f) where conditions are favourable for the formation of lee troughs and lows in the Alboran Basin, the Straits area and in the Gulf of Cadiz, the diagrams must again be used with caution and in the context of each situation.

5. Surface Winds.

5.1 Climatology.

5.1.1. A computer analysis of surface wind directions and speeds recorded at North Front in the years 1947-66 was carried out, and in Figs. 6 to 8 are shown the results in graphical form for (a) the whole year (b) the summer months (Jun/Jul/Aug) and (c) the winter months (Dec/Jan/Feb).

5.1.2. The annual results clearly demonstrate the predominance of winds from the easterly and westerly quarters. Of winds in the southerly quarter the majority lie in the 190-220 deg. sector whilst winds in the 150-180 deg. sector are comparatively rare as are winds from the northerly quarter. Calms are also relatively infrequent.

5.1.3. It will also be noted that the easterlies tend to be fairly closely grouped around 090 deg. whilst by comparison the westerlies have a broader spectrum of direction centred around 255 deg. In each case, however, there is a rapid cut-off in frequency with a progression of direction to more northerly or southerly points.

5.1.4. In the summer months (Fig. 7) easterly winds predominate. It will also be noted that with westerlies the highest frequencies lie in the 230, 240 and 250 deg. sectors - a clear manifestation of the effects of the summer sea-breeze component.

5.1.5. In the winter months (Fig. 8) westerlies are predominant with the highest frequencies in 270, 280 and 290 deg. sectors.

5.1.6. The transitional months from the predominant winter westerlies to summer easterlies and vice versa are Apr/May and Sept/Oct respectively.

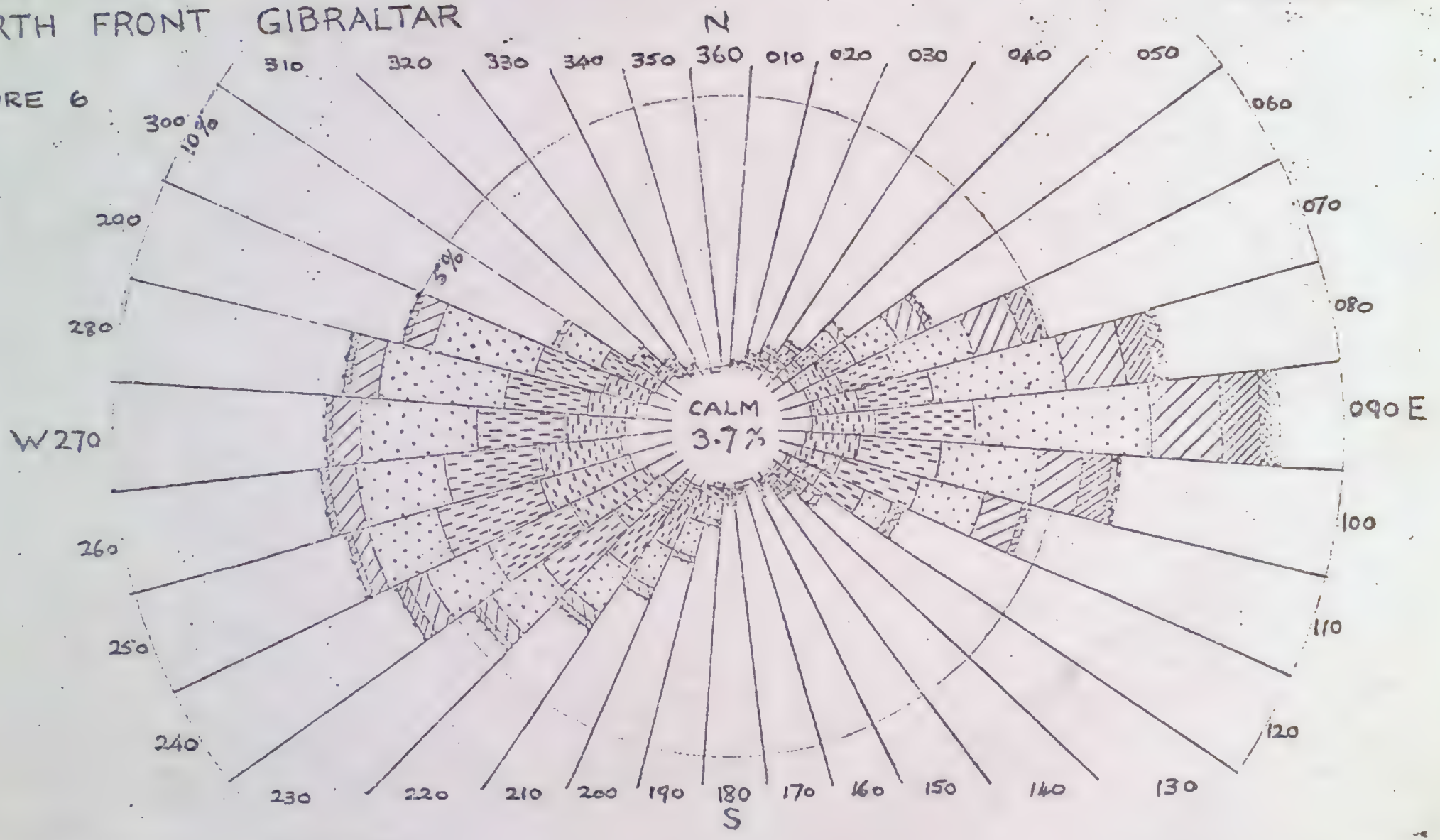
5.1.7. Another analysis of North Front data covering the years 1958-66 is given in Table Ia . The general trends of the earlier analysis in respect of directions are confirmed. For the convenience of the reader, the percentage frequencies of westerlies, easterlies and calms in the 1958-66 period and of winds from all directions in the 1947-71 period are shown in graphical form in Figs 9a and 9b respectively.

5.1.8. Monthly and annual percentage frequencies of wind speeds in the Beaufort force ranges of 0-1, 2-3, 4-5, 6-7, and 8 and over are also given in Table Ib and the predominance of higher wind speeds in the winter months is evident. It will also be noted that nearly 80 percent of all winds during the year lie in the range force 2-5.

SURFACE WIND 1947-1966
NORTH FRONT GIBRALTAR

ANNUAL

FIGURE 6



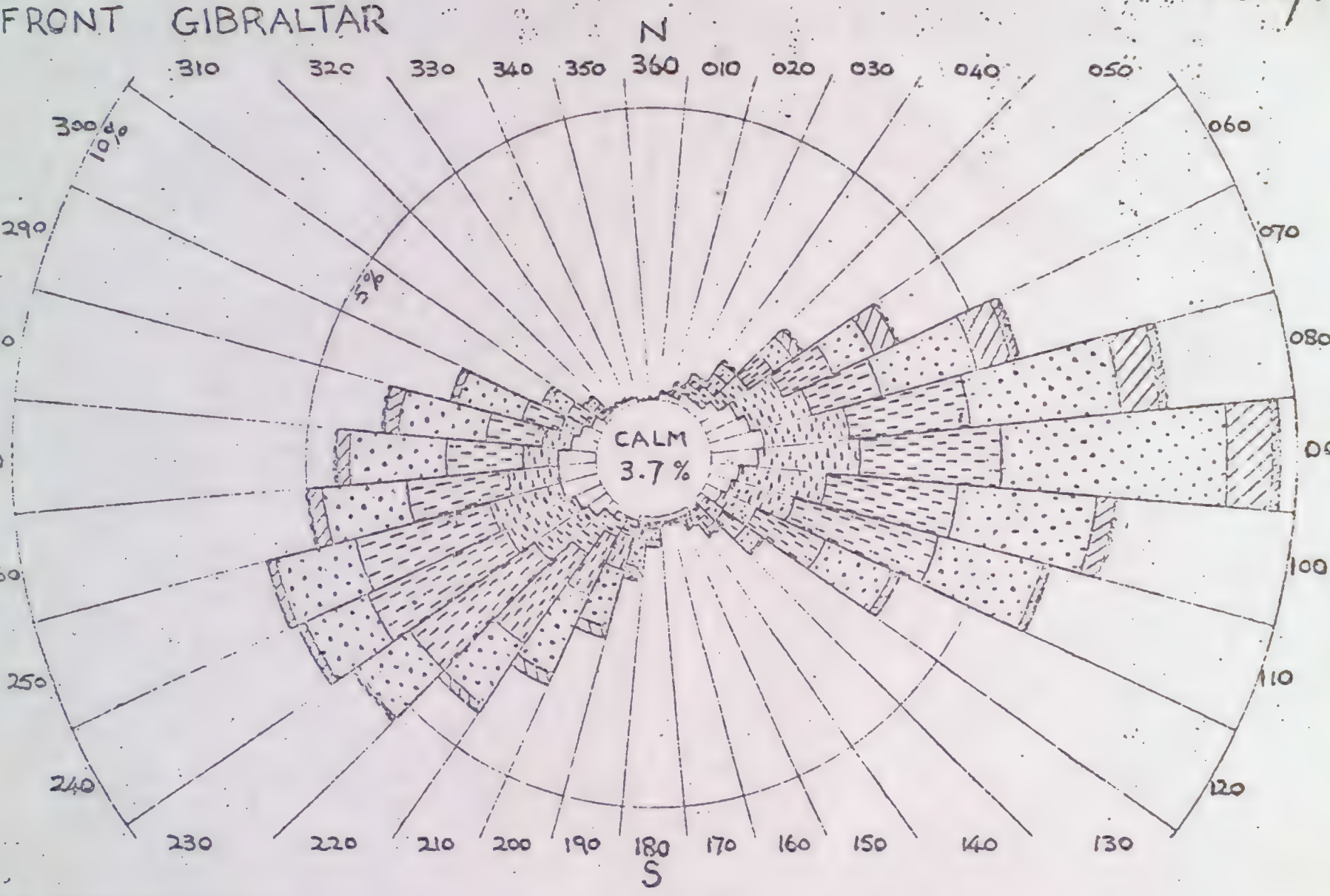
FORCE 1 2 3 4 5 6 7 (8)

1 CM. = 1%

SURFACE WIND 1947-1966
NORTH FRONT GIBRALTAR

JUN/JUL/AUG

FIGURE 7



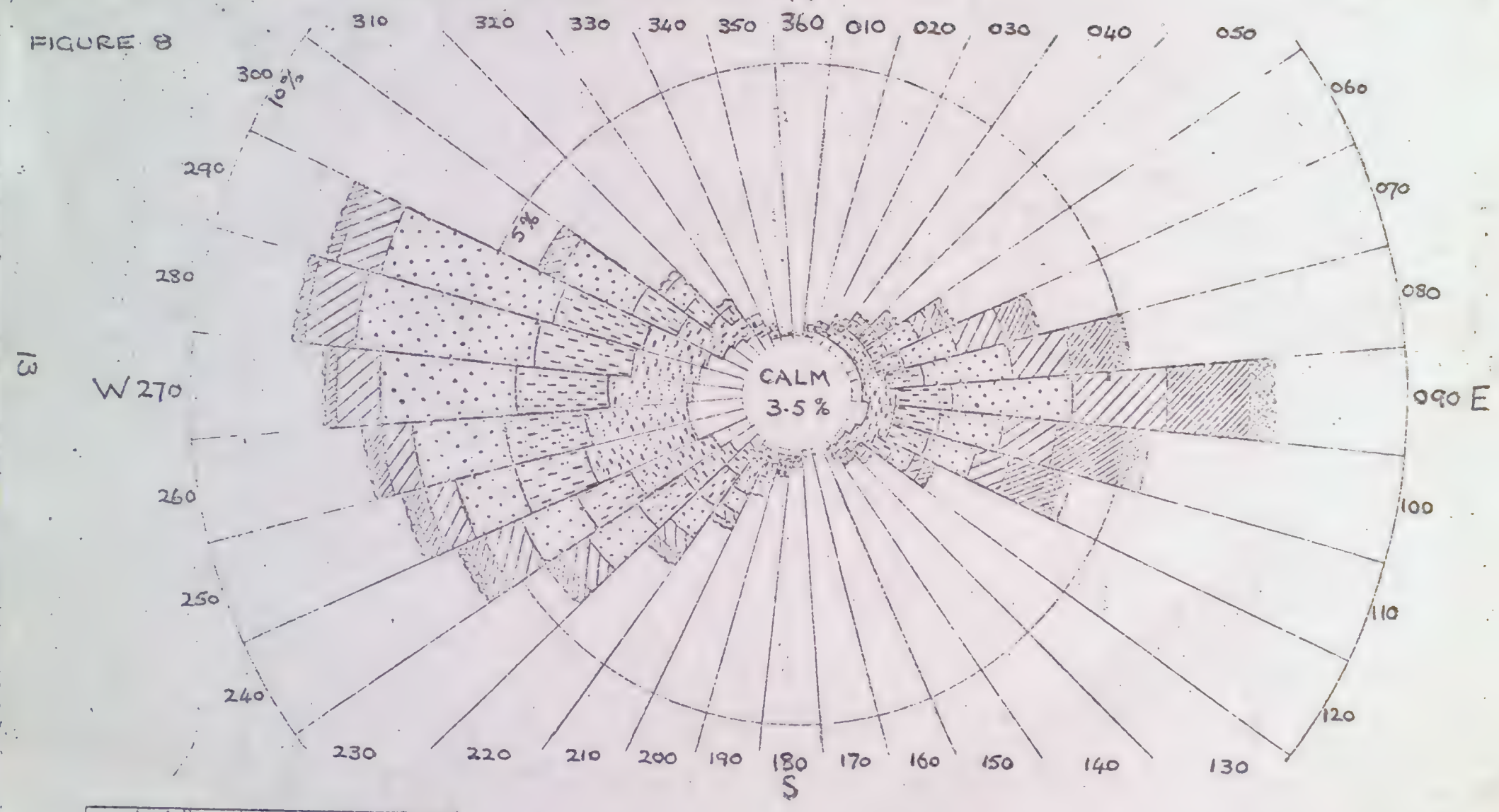
FORCE 1 2 3 4 5 6 7+

1 CM. = 1%

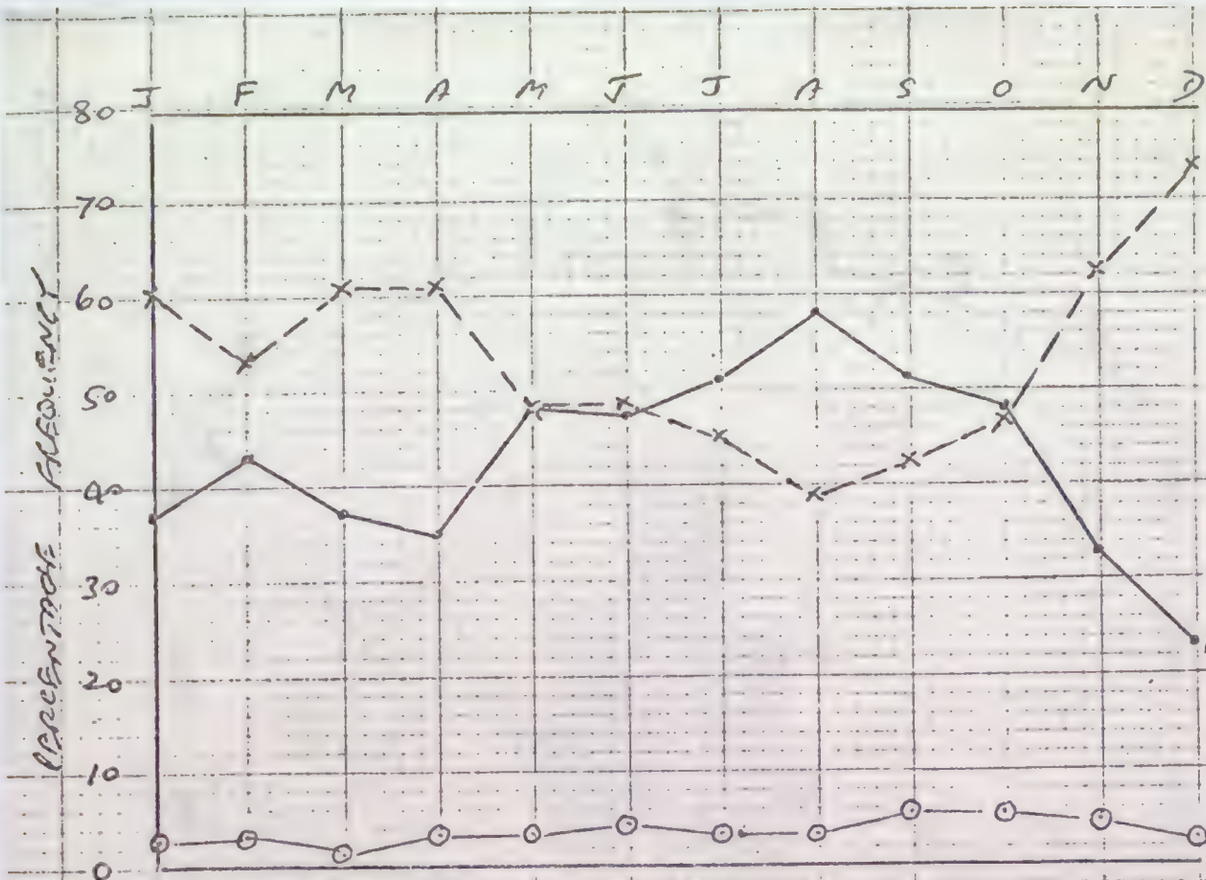
SURFACE WIND 1947-1965
NORTH FRONT GIBRALTAR

DEC/JAN/FEB

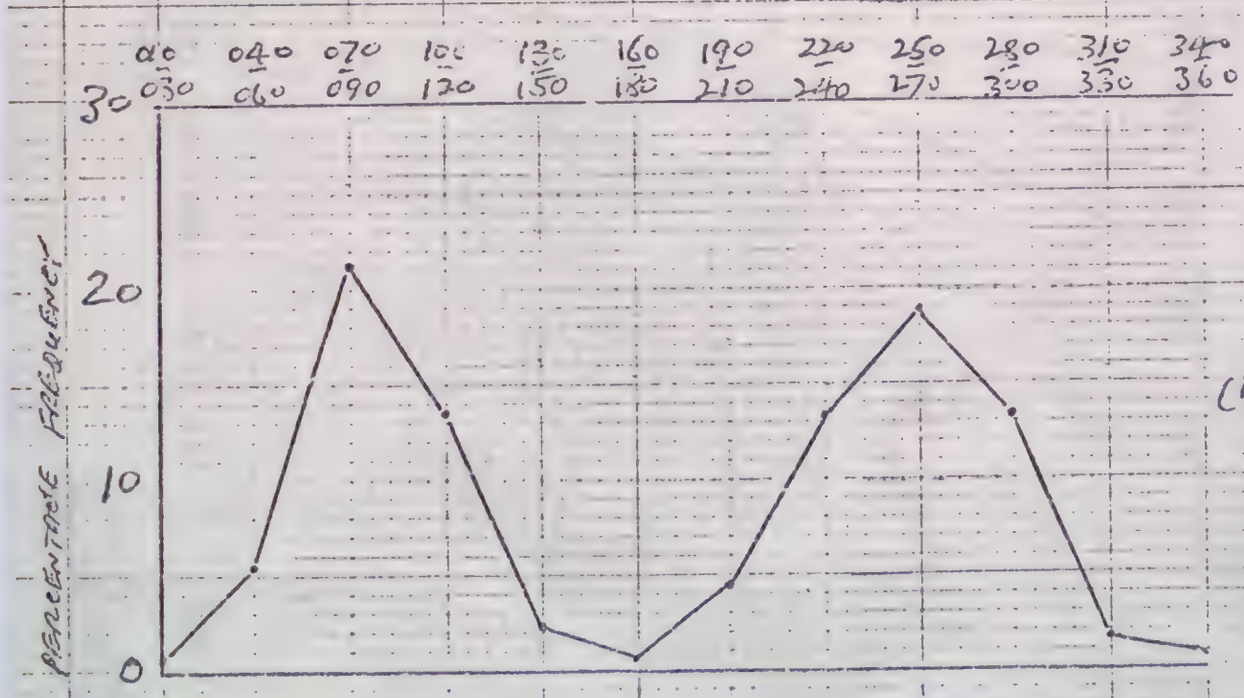
FIGURE 8



1 CM. = 1 %-



PERCENTAGE FREQUENCIES OF (A) WESTERLY WINDS (B) EASTERLY WINDS AND (C) CALMS AT GIBRALTAR (1958-1966 DATA)



PERCENTAGE FREQUENCIES OF WINDS FROM DIRECTIONS IN RANGES STATED AT GIBRALTAR - (ALL MONTHS 1947-71)

Figs 9a & 9b

PERCENTAGE FREQUENCIES OF SURFACE WIND DIRECTION AND SPEED AT GIBRALTAR (BASED ON 1958-1966 DATA - ALL HOURS)

DIRECTION

DIR°T \ MONTH	J	F	M	A	M	J	J	A	S	O	N	D	YR
CALM	3·0	3·4	1·5	3·4	3·5	4·1	3·9	3·4	5·9	5·5	4·6	2·8	3·8
001 - 030	0·7	1·0	0·5	0·4	0·3	0·2	0·3	0·2	0·3	0·7	0·9	0·9	0·5
031 - 060	2·1	2·4	1·6	2·7	2·2	2·8	3·4	2·8	3·6	4·9	3·8	2·6	2·9
061 - 090	15·3	13·9	15·2	14·1	20·6	17·8	18·4	22·7	23·8	25·8	15·2	10·3	17·7
091 - 120	16·0	22·4	16·6	13·4	19·8	21·2	24·5	26·1	20·8	13·5	10·2	7·6	17·6
121 - 150	2·5	2·5	2·7	4·2	5·0	5·1	3·9	5·7	2·9	2·3	2·2	1·6	3·4
151 - 180	0·3	0·5	0·6	0·4	0·4	0·2	0·2	0·1	0·2	0·4	0·6	0·5	0·4
181 - 210	1·5	1·6	2·2	3·5	2·8	4·2	4·3	3·6	3·6	3·0	3·7	3·2	3·1
211 - 240	12·1	11·8	10·4	11·6	11·4	12·3	13·8	10·5	10·8	10·4	11·4	14·2	11·7
241 - 270	18·0	18·9	21·1	23·0	18·4	18·7	15·2	15·3	16·3	17·5	23·5	23·4	18·8
271 - 300	23·2	17·7	24·3	21·2	13·1	12·0	10·3	8·8	10·4	13·9	21·6	26·9	17·0
301 - 330	4·8	3·6	3·1	2·8	2·2	1·3	1·1	0·7	1·2	1·7	2·9	5·4	2·7
331 - 360	0·5	0·3	0·2	0·3	0·3	0·1	0·7	0·1	0·2	0·4	0·4	0·6	0·4
001 - 180	36·9	42·7	37·2	35·2	48·3	47·3	50·7	57·6	51·6	47·6	32·9	23·5	42·5
181 - 360	60·1	53·9	61·3	61·4	48·2	48·6	45·4	37·0	42·5	46·9	62·5	73·7	53·7

a

SPEED (BEAUFORT FORCE)

FORCE \ MONTH	J	F	M	A	M	J	J	A	S	O	N	D	YR
0-1	14·3	15·4	9·6	17·3	16·1	16·1	15·4	15·1	21·4	19·7	21·4	15·0	16·4
2-3	36·0	37·3	37·7	45·3	49·2	49·3	52·2	52·7	52·0	44·4	48·6	35·3	44·6
4-5	39·0	34·6	44·1	35·5	33·5	34·1	32·2	32·0	26·2	34·0	32·3	42·6	35·0
6-7	10·2	11·7	8·4	1·9	1·2	0·5	0·2	0·2	0·4	1·9	2·4	6·8	3·8
8 and over	0·4	1·0	0·2	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·3	0·3	0·2

b

PERCENTAGE FREQUENCIES BASED ON 1947-1971 DATA

Dirn °T	ALL SPEED	F3 and below	Force 4	Force 5 and above
010 - 030	0·7	0·5	0·1	0·1
040 - 060	5·5	3·3	1·4	0·8
070 - 090	21·1	8·5	7·1	5·5
100 - 120	13·5	7·4	3·5	2·6
130 - 150	2·1	1·5	0·35	0·25
160 - 180	0·8	0·6	0·2	0·0
190 - 210	4·5	2·1	1·8	0·6
220 - 240	13·4	8·5	3·3	1·6
250 - 270	18·9	12·0	5·0	1·9
280 - 300	13·3	6·8	5·0	1·5
310 - 330	1·7	1·2	0·3	0·2
340 - 360	0·8	0·8	0·0	0·0
Calm	3·7	3·7		
Totals	100·0	56·8	28·05	15·15

c

Tables I a-c

Table II Analysis of Gales at Gibraltar 1947-76

Duration (hrs)	No. of Occurrences Easterly	Westerly
3	31	37
4-6	11	13
7-12	10	6
13-18	7	2
19-24	8	-
25-30	6	-
31-36	3	-
37-42	1	-
43-48	-	-
49-54	-	-
55-60	-	-
61-65	1	-
65	-	-
Total	78	58

Maximum hourly mean wind speeds recorded in the period were:-

With easterlies 53 kn 23-24 Jan. 1963
" westerlies 47 kn 13-14 Jan. 1969

Maximum gusts recorded were:-

With easterlies 68 kn 23-24 Jan. 1963
" westerlies 79 kn 30 Nov. 1959

5.1.9. In Table Ic are also the percentage frequencies of winds in the speed ranges - calm, force 3 and below, force 4, and force 5 and above for each sector of 30 deg. from 010-030, 040-060, etc. These clearly show that strong easterlies blow for a much higher proportion of the year than do strong westerlies, and that strong northerly winds are extremely rare.

5.1.10. Mean monthly wind speed based on 1956-76 data for North Front show February to be the windiest month (mean speed 13.4 kn) whilst September is the least windy month (mean speed 9.5 kn).

5.1.11. Additional wind frequency tables for North Front and Windmill Hill may be found in pages 162 and 261 of Ref. 46 and in a paper by Ward (Ref. 4).

5.2 Gales

5.2.1. Table IX (page 38) shows that gales at Gibraltar occur on an average of about 3½ days per year, and that they are most likely to occur from November to March. Gales in April are by comparison rare, and in May to September almost unknown.

5.2.2. Easterly gales and near gales occur more frequently than do westerly gales or near gales, and are usually longer lived. An analysis of North Front winds over 34 kn indicated (= 31 kn corrected for the effective height of the anemo - meter) in the years 1947-76 is given in Table II . The ratio of easterly gales or near gales to those with westerlies was found to be 78:58. The tendency for easterly gales to last longer than westerly gales is also evident. As a rule, however, westerly gales although usually short lived are stronger and more gusty than easterly gales.

5.2.3. Seasonal percentage frequencies of gales in the Straits and in the Alboran Basin are to be found in Table 12, page 90 of M0391 (Ref. 6). It is noteworthy that, in the Straits, the highest percentage frequency of gales occurs with easterlies, whereas in the Alboran Basin the reverse is true. The first fact is due to the massive dam effect of the high ground bordering the Alboran Basin with no major outlet to the west other than the Straits. The second fact may at first sight appear somewhat paradoxical in that the Alboran Basin widens very rapidly eastward of Gibraltar and Ceuta, and one would expect eastgoing air from the Straits to decelerate rapidly. However, with strong low level flows from the western semicircle lee lows or troughs are readily formed in the Alboran Basin causing large local variations in the magnitude and direction of surface pressure gradients. This is particularly true of northwesterly flows which often give rise to gale force southwesterlies in the southern part of the Alboran Basin despite the fact that the surface wind in the Straits may be well below gale force and those in the northern part of the Basin may be much lighter and variable in direction. An example of this is to be found in Fig. 51 (Appendix B).

6. Easterly Situations

6.1 In Figs. 19 to 26 are shown some of the more commonly observed synoptic situations leading to the establishment of easterlies in the Straits area.

6.2 The sequence at Figs. 10 to 11 is probably the most common. The extension of the Azores High into Central Europe becomes displaced southwards towards the Mediterranean as a warm sector approaches the UK from the Atlantic. The North African trough and the Atlantic high cell become displaced westwards and an easterly flow becomes established in the Straits. A lee low is then usually formed just off the Moroccan coast between Cape Spartel and Casablanca - a feature which often shows up very clearly in satellite pictures. Depending on the strength of the flow through the Straits, SSE'ly winds on the northern flank of such a low are frequently much stronger than those observed at Tangier and often extend in a narrow band of less than 10 nm wide as far as 7 or 8 degrees west with relatively much lighter winds on either side of the band (Fig. 26).

6.3 The type of situation described in 6.2 occurs in both summer and winter. In summer, however, the normal heat low over Spain frequently becomes displaced westwards when such an easterly becomes established in the Straits and becomes amalgamated with the North African trough to form an elongated trough extending from Cape Finisterre down into Morocco (Fig. 3). In such a case, the flow over Gibraltar is usually SE or SSE bringing air of desert origin into the Straits and Alboran Basin areas. The resulting low humidities give rise to pleasant cloud free easterly weather conditions at Gibraltar instead of the more humid conditions and levanter cloud normally associated with summer easterlies at this station.

Another consequence of this situation is the reinforcement of the Portuguese Trades which can often reach gale force with very rough sea conditions especially west of Cape Finisterre and southwards at about 10 deg. W. as far as 35 deg. N.

6.4 The situation at Figs 18-19 shows the movement of a cut-off low from the Atlantic into the Gulf of Cadiz resulting in the establishment of an easterly flow in the Straits area. Such lows are most commonly first observed in the area just east of the Azores and less commonly to the south or southeast of the Azores. It will be readily evident that when the low is established in the Gulf of Cadiz the upper flow in the Gibraltar area will be southwesterly with a surface and low level easterly flow. This is of course, the well-known CONTRASTE situation mentioned in para 2.5 which can give rise to substantial rainfall at Gibraltar

6.5 Another situation leading to the development of a CONTRASTE is that at Figs 20-21. A cold pool over N. France moves southwest across Biscay and then S down the Portuguese coast. A surface low usually begins to form in the region of Cape Finisterre and deepens as it moves south in association with the cold pool. Having reached SW Portugal the preferred track of such a low is eastwards

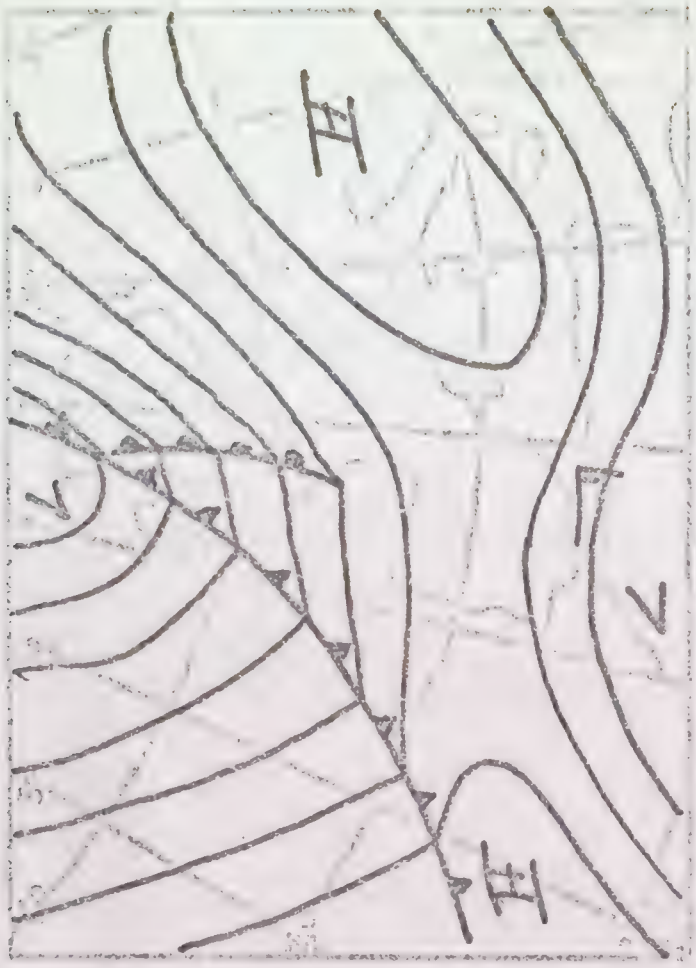


Fig 11

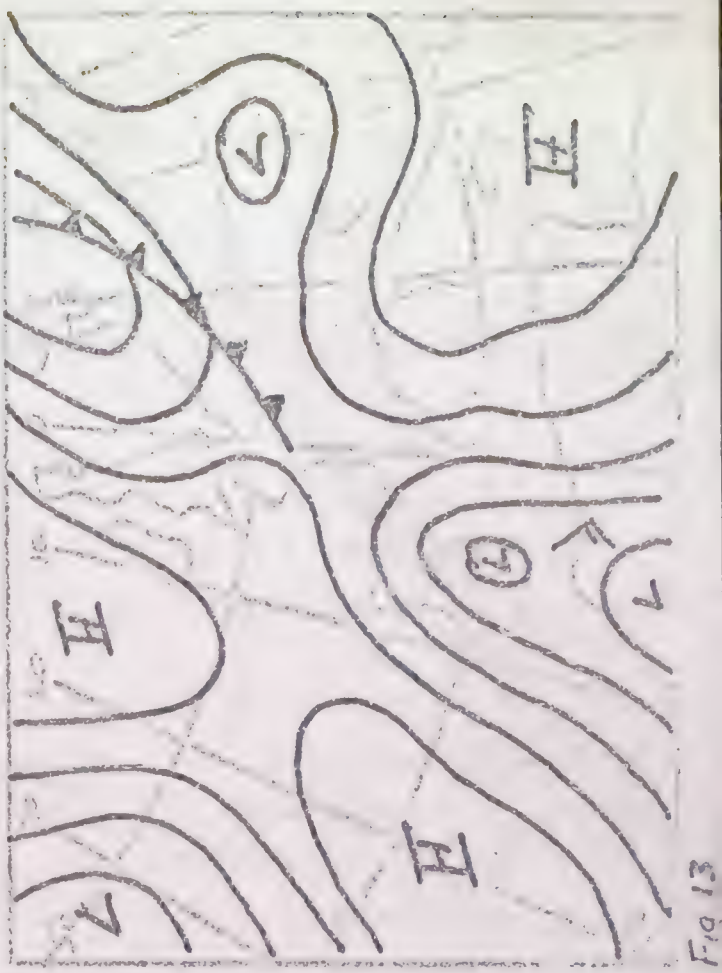


Fig 13

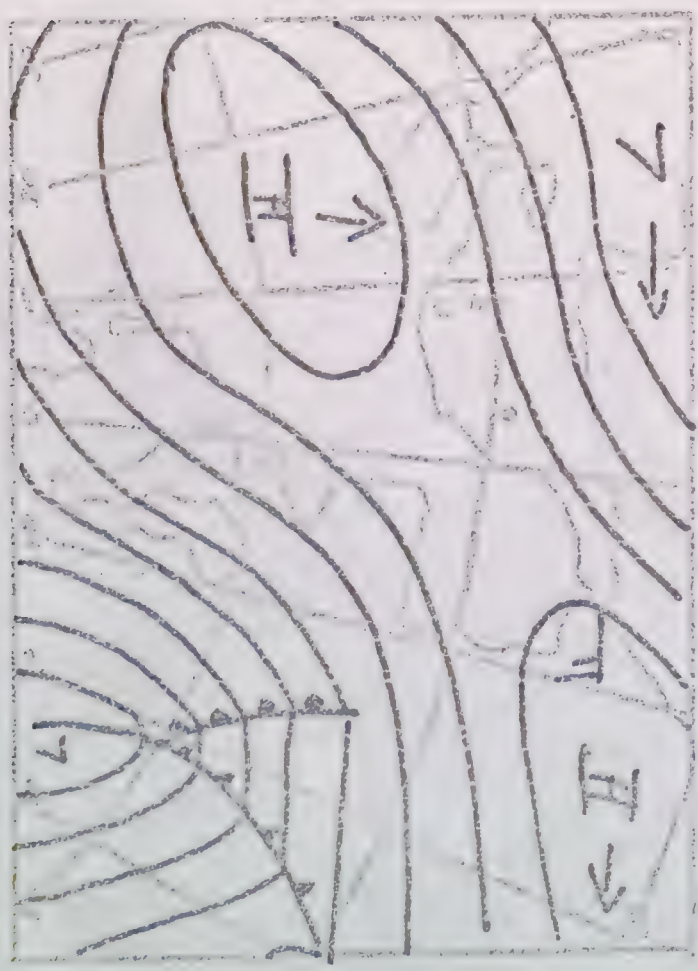


Fig 10

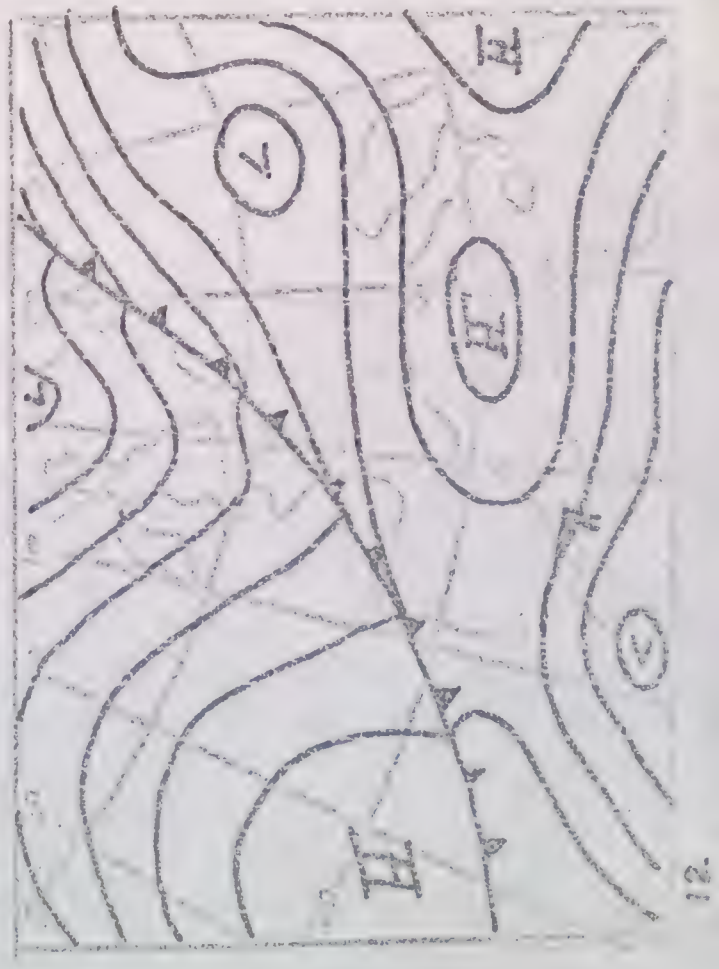
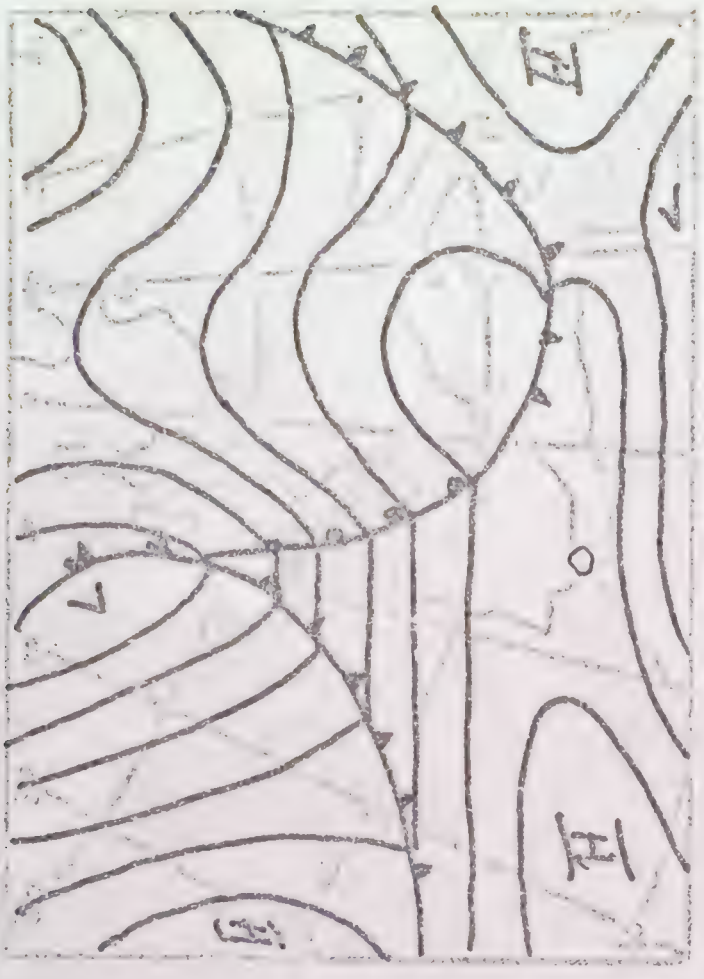
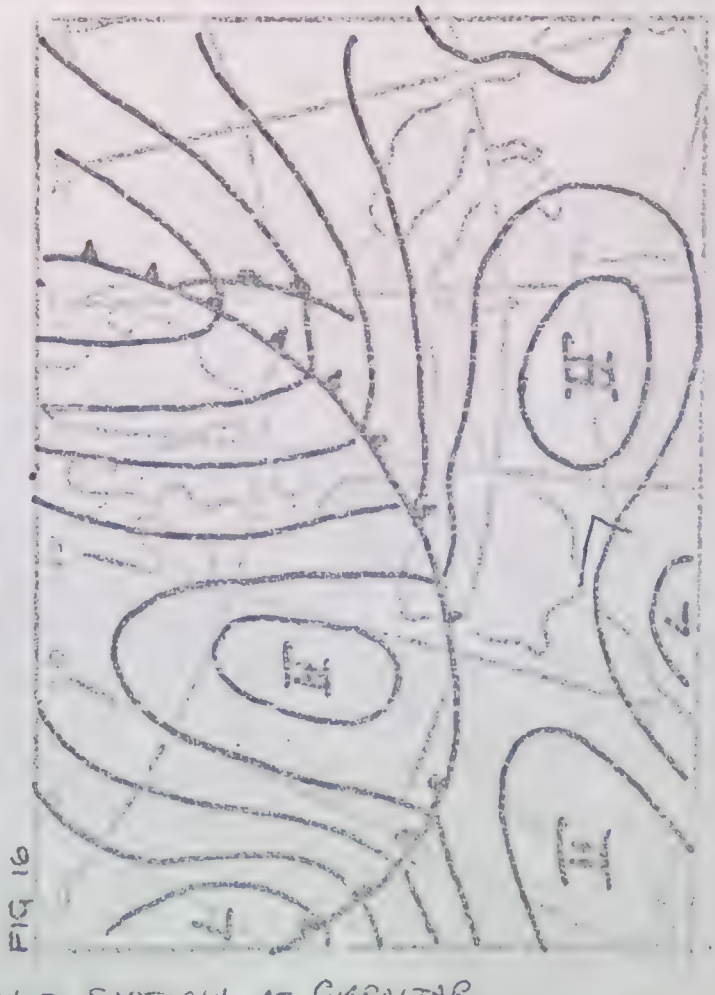


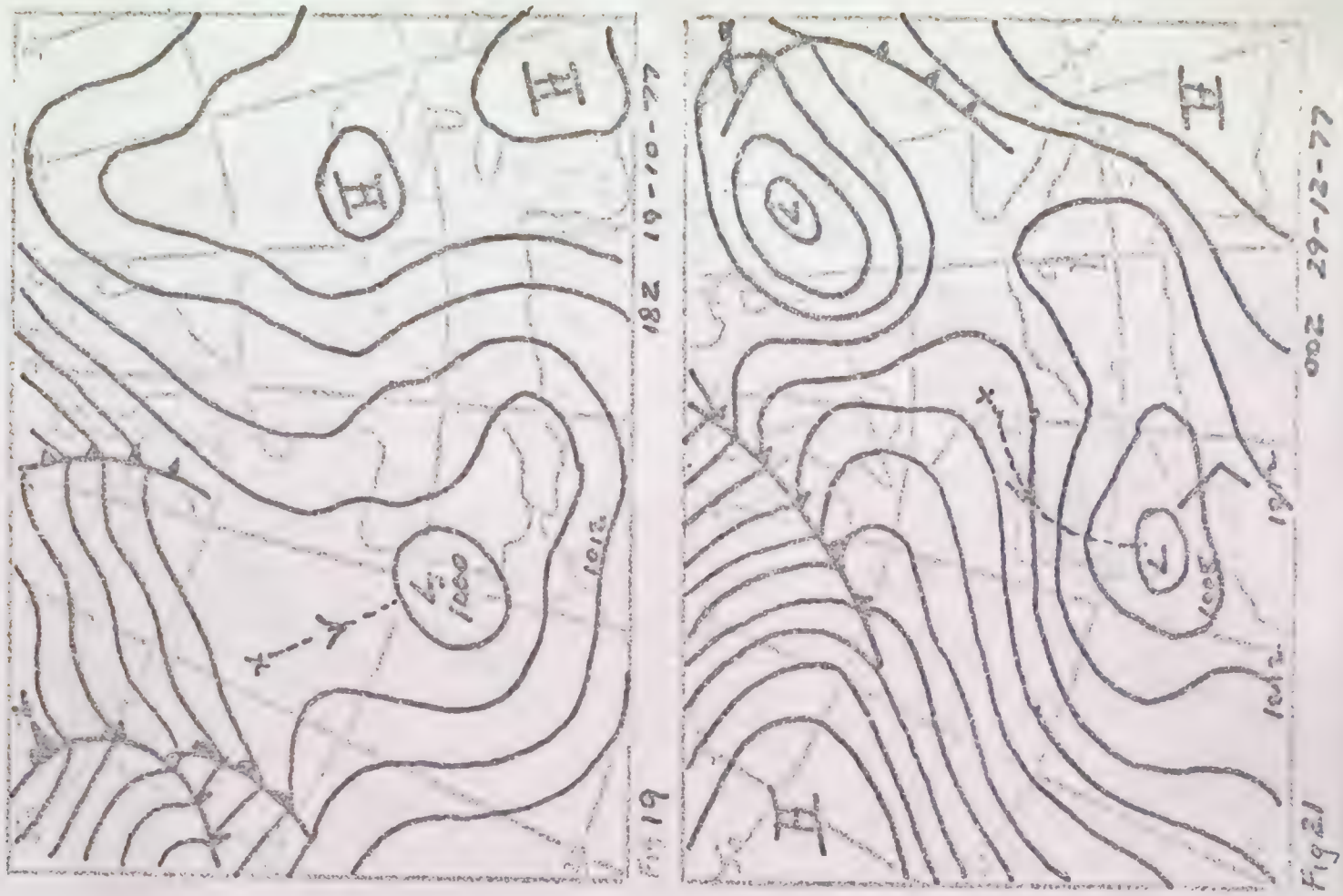
Fig 12

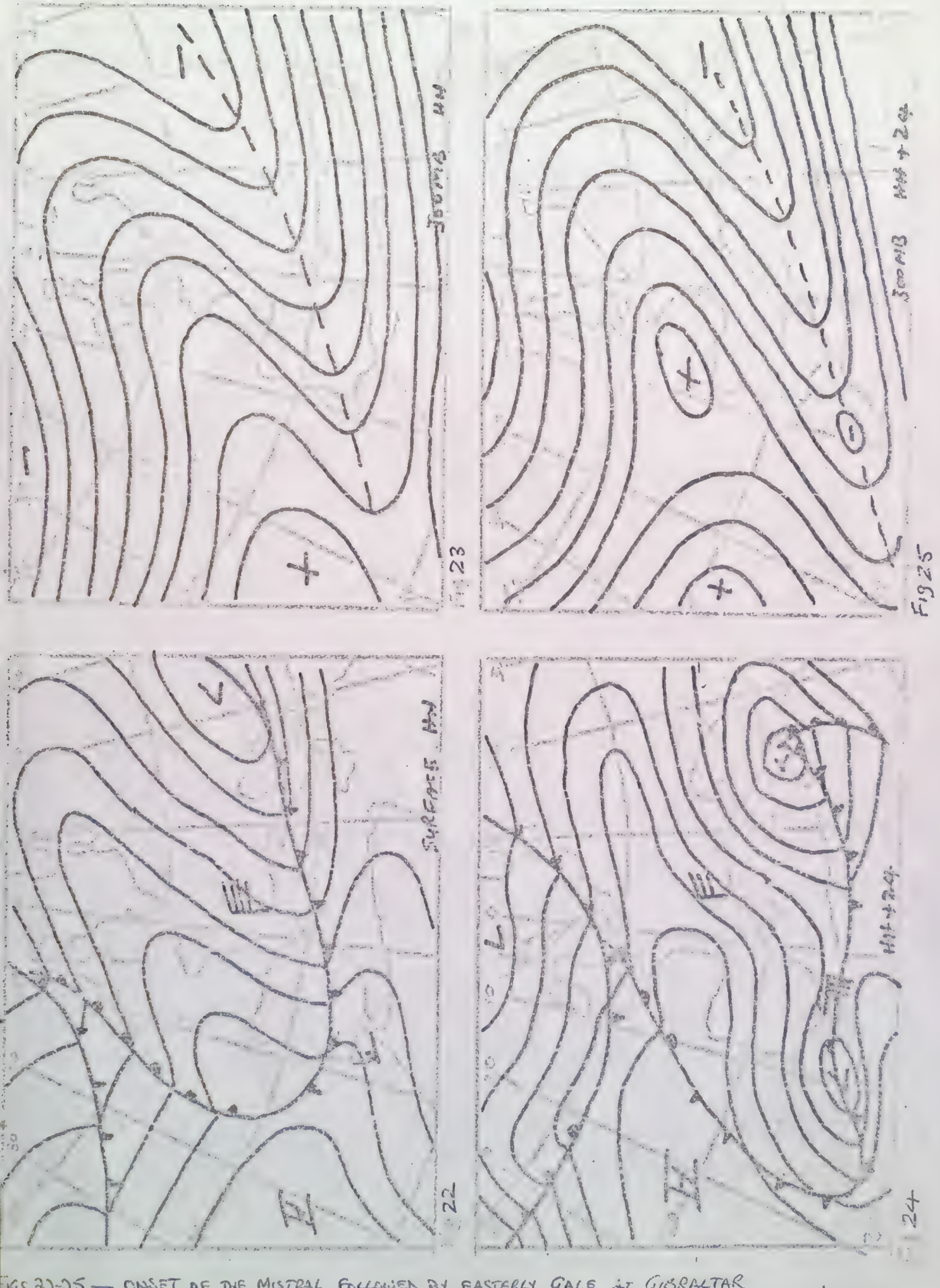
FIGS 10-13 — EASTERLY SITUATIONS AT GIBRALTAR





FIGS 14-17 — CHANGE FROM WESTERLY TO EASTERLY AT GIBRALTAR


H
H
H
1000
1012
1016
1008
1012
1008
1012
1016
1008
1012
1016
1008
1012
1016



FIGS 22-25 — ONSET OF THE MISTRAL FOLLOWED BY EASTERLY GALE AT GIBRALTAR

through the Straits. Occasionally, however, it may continue southsoutheast to to enter Morocco and then pass eastwards south of the high Atlas to eventually re-enter the Mediterranean in the vicinity of Malta - frequently with considerable re-intensification.

6.6 Figs. 22 to 25 show a typical change from westerlies to easterlies at Gibraltar following the onset of the MISTRAL (usually within 24-36 hrs). This usually requires the upper flow (eg at 300 mb level) over S. France to veer beyond 020-030 deg. If this veer does not occur a ridge pattern is established to the west of the Straits and easterlies do not occur. If the veer over central and southern Spain is beyond 040-050 deg., easterlies in the Straits generally become strong.

6.7 Easterlies at Gibraltar can develop from a variety of other synoptic situations eg. developing warm front and cold front waves moving southeast or northeast towards the Gulf of Cadiz, and some examples of such situations are given in Appendix B to these notes and in pages 203-357 of Met O 391 Vol.I (Ref 6)

7. Westerly Situations

7.1 In Figs. 27 to 30 are shown some typical synoptic situations leading to westerlies at Gibraltar and in the Straits area.

7.2 That at Fig.27 is a common winter situation giving rise to strong westerlies at Gibraltar. The associated strong NW'ly flow over Spain leads to marked troughing in the Alboran Basin and off the southeast coast of Spain, and frequently leads to gale force southwesterlies in the Basin south of 36 N whilst in the northern half of the Basin winds are comparatively light northeasterlies. Such a situation can be seen in the large scale chart at Fig. 51 (Appendix B)

7.3 Fig.28 also shows a frequent winter situation giving rise to strong gusty southwesterlies at Gibraltar and heavy showers or thunderstorms as the cold front passes through to the east. Further troughs develop in the western sector of the major low northwest of Cape Finisterre, and an improvement in the weather at Gibraltar may occur as the first cold front goes through and the wind may veer to W or NW, this is generally temporary and winds soon back to the southwest and showers continue. In some cases a separate centre forms near Cape St. Vincent and moves east into the Gulf of Cadiz to create a CONTRASTE situation. There is no permanent improvement at Gibraltar until the upper trough moves east of the station and a true northwesterly flow becomes established aloft over the Straits area.

7.4 Fig.29 shows the development of a ridge over western Iberia and Morocco ahead of a slow-moving low in the area between the Azores and Madeira - a not too infrequent situation of the summer months when light and humid easterlies are, as a consequence, replaced by light or moderate and drier westerlies.

7.5 The end of a CONTRASTE situation which occurred as a result of a cold front wave is shown at Fig.30 . As the centre moves east across Gibraltar into the Alboran Basin, there is a rapid change from easterlies or southeasterlies to southwesterlies, usually strong and gusty, as the cold front approaches the western Straits. With the passage of the front wind veers rapidly to W or NW and the weather clears as the upper trough moves east of the station. Despite the comparatively strong northerly or northeasterly orientation of the surface isobars, it is rare for surface winds at Gibraltar to veer beyond northwest.

7.6 A typical sequence of change of easterlies to strong westerlies and back to easterlies over a period of 48-72 hrs is shown in Figs. 31 to 34 as depressions move west to east across the British Isles. Such marked changes are generally a feature of the autumn, winter and spring months - those of the summer months tend to be more leisurely and less pronounced.

7.7 Other examples of westerly situations are to be found in Appendix B to these notes.

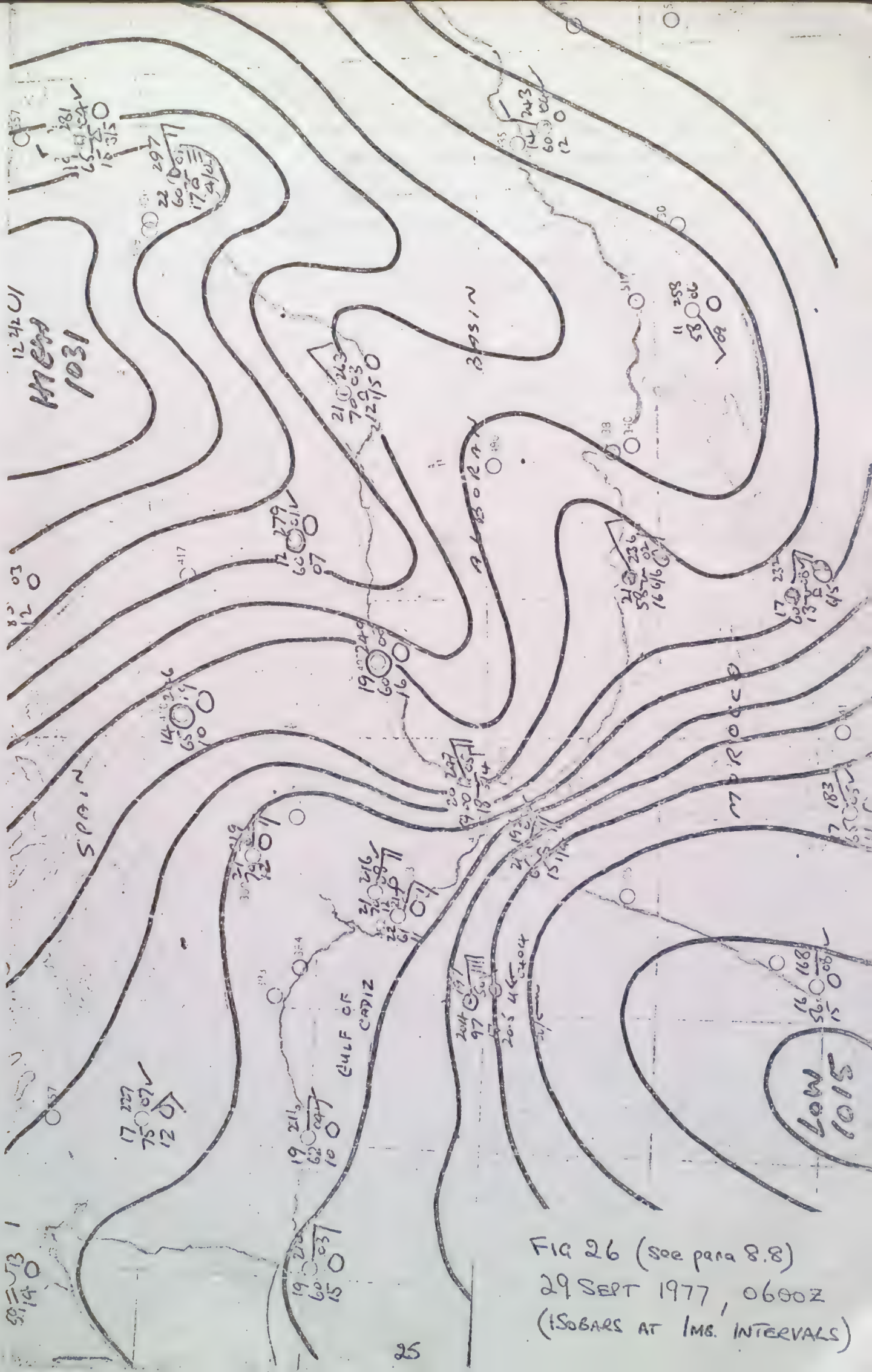
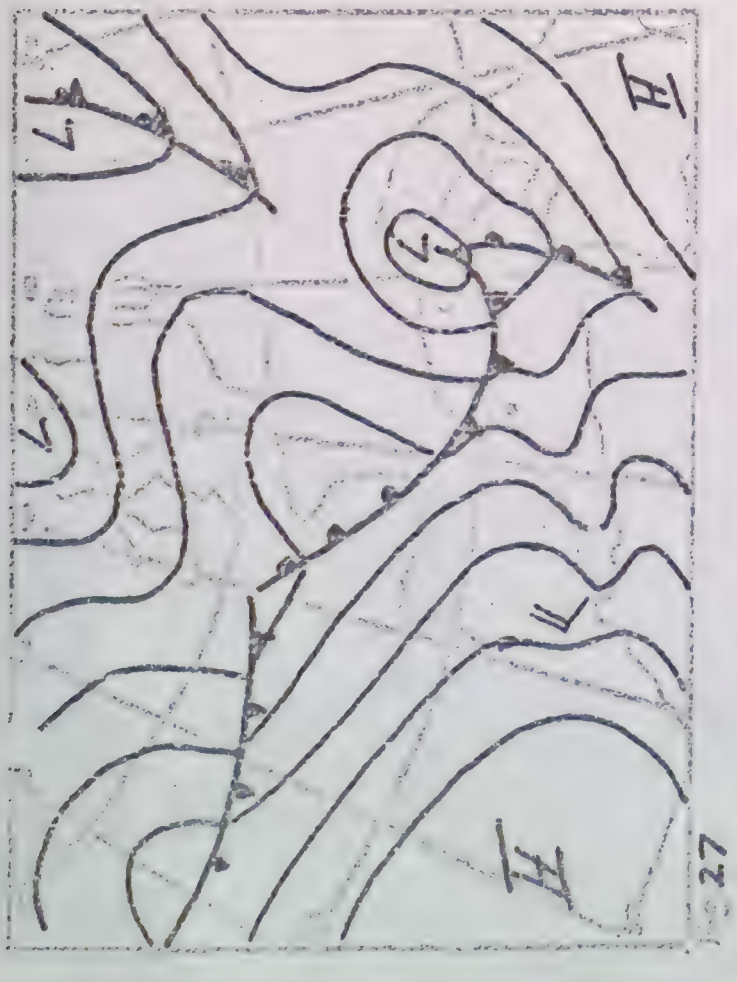


FIG 26 (see para 8.8)
29 SEPT 1977, 0600Z
(ISOBARS AT 1MB. INTERVALS)



FIGS 27-30 — EXAMPLES OF WESTERLY SITUATIONS

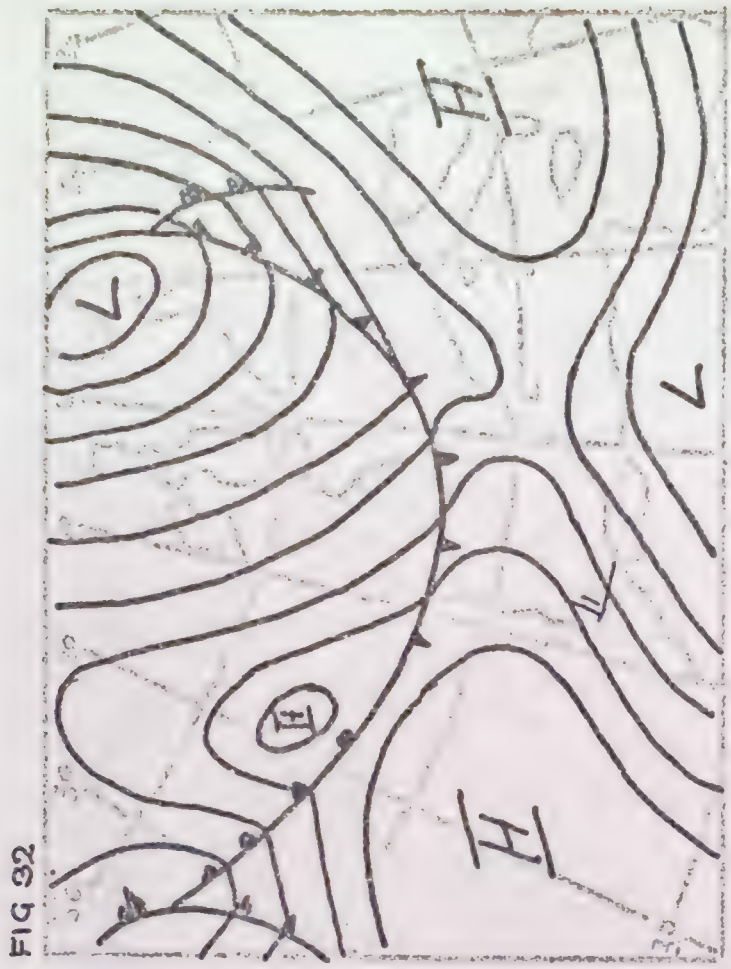


FIG 32

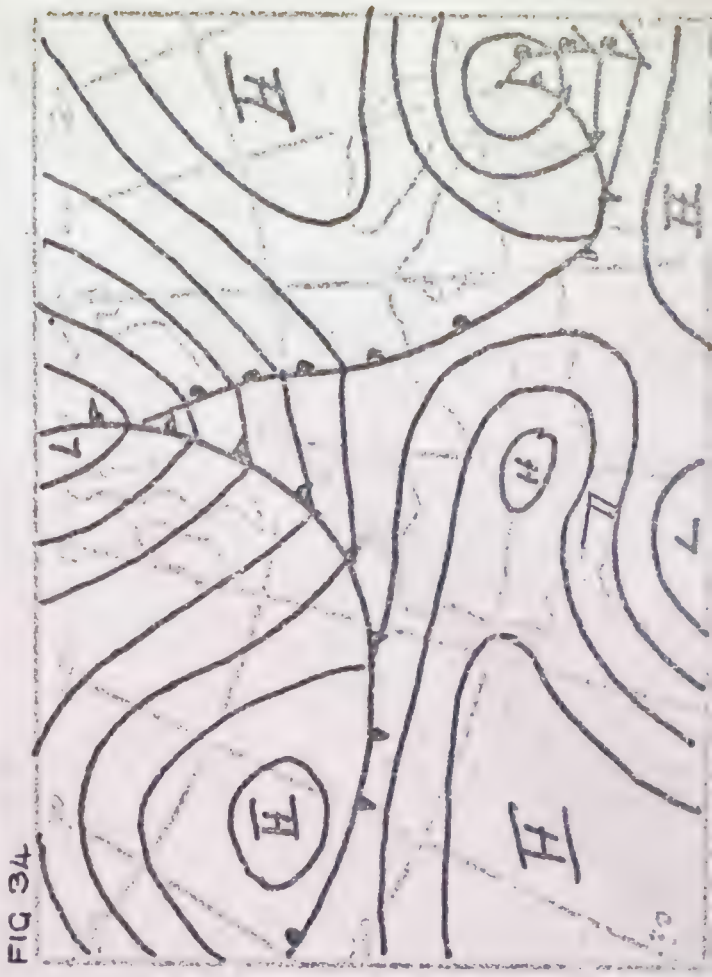


FIG 34

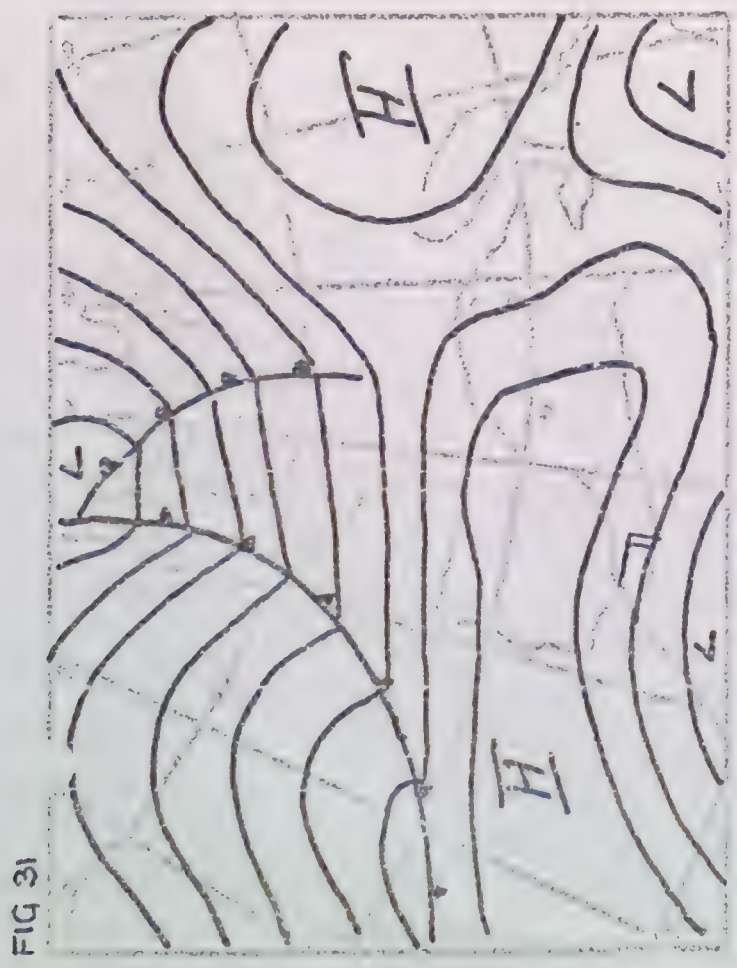


FIG 31

FIG 33

FIGS 31-34 — CHANGE FROM EASTERLIES TO STRONG WESTERLIES AND BACK TO EASTERLIES AT GIBRALTAR

8. Features of Easterly Winds at Gibraltar

8.1 Easterly winds at North Front are remarkably steady in both speed and direction unless they are associated with:-

(a) low level instability sufficiently deep to permit the formation of large cumulus and the development of showers - usually a winter occurrence.

(b) the passage of surface or upper troughs through the Straits area.

(c) a southerly flow (160-220 deg) of upwards of 15 kn. overlying the low level easterlies in the Straits area and separated from it by a well marked inversion (usually between 3000 and 5000 ft) - a common summer feature. In this case wave motion induced by the N.African mountains in the southerly flow produces a pumping effect on the low level easterly flow giving rise to regular oscillations of surface wind speed at North Front. Speeds may vary from near zero to 20-25 kn. over periods of 15-20 minutes.

(d) middle-level instability in a southerly flow overlying the low level easterlies. In such cases patches of Ac Castellanus are almost always present in the Straits area, and as they drift northwards in the vicinity of Gibraltar marked gustiness of the surface wind is often experienced at North Front. Such gustiness is, however, much more random in character than in the case described at (c) above. This situation is again most probable in the summer months.

8.2 As is well known, easterlies of 20 kn or more cause frequent squalls in the Harbour and Bay areas. During the day, the City area, excluding the housing estates at the northern end of the Rock, is usually sheltered and unaffected to any great extent by such squalls. At night however, even with free wind speeds of less than 20 kn, fierce gusts are frequently experienced in the City area, especially in the districts around Southport Gates and Humphries Flats. Even in the summer months residents in these areas are frequently awakened in the early hours of the morning by the banging of windows etc as the gusts commence.

8.3 With easterly winds of the order of 30 kn or more, squalls in the Bay and Harbour areas are usually violent and accompanied by much spray. In general the worst affected area in such conditions is that just west of the northern end of the detached mole where a predominantly southerly flow merges with a northeasterly flow from the airfield area. Rapidly rotating vortices are formed giving rise to columns of spray which travel quickly westwards before dissipating over the western side of the Bay. With easterlies of this strength severe turbulence may affect the last mile of the approach to Runway 09. Gust speeds associated with such squalls have been estimated by several experienced observers to be in the order of twice the free wind speed at Rock top level.

8.4 In the Straits wind speeds in easterly situations just south of Tarifa Point are usually about twice those recorded at North Front. The width of the band of strong winds in this area can be as little as 2 nm and extends as a thin stream westwards to about 7°W. Outside this band, winds in the Straits area are generally stronger than those at North Front by a factor of about 1½.

8.5 Strong easterlies in the Straits blowing from just north of east can cause very heavy sea conditions in Tangier Bay and harbour which causes much difficulty to shipping attempting to enter or leave the port.

8.6 Strong easterlies in the Straits areafrom between 100 and 130 deg. almost always give rise to very severe low level (below 5000 ft) turbulence on the flight path out of Tangier Airport especially over Tangier Bay. It is suggested that the problem is accentuated by the inter-action of wave trains generated by the several ranges of hills lying between Tetuan on the Mediterranean coast of Morocco and Tangier.

8.7 With an approaching trough just west of the Straits giving rise to fresh or strong easterlies in the Straits and a fresh or strong southwesterly flow west of the Straits, the converging flows give rise to gale force south-south-easterlies from Cape Trafalgar to Cadiz. Also the associated southwesterly Atlantic swell combines with wind generated waves moving westwards from the Straits to produce very rough and chaotic sea conditions in the Gulf of Cadiz which are very dangerous to small craft and can cause concern to even moderately sized vessels.

8.8 It often happens in easterly situations, particularly with SSE-NNW orientated isobars, that the majority of the Ali-Cas pressure difference lies between Gibraltar and Tangier. In such circumstances, winds at Gibraltar can be fairly light whilst at the western end of the Straits they are strong or even gale force. An example of this is given in Fig. 26.

8.9 As a general rule strong easterly winds at Gibraltar moderate rapidly as one proceeds northwards along the Mediterranean coast of southern Spain towards Estepona.

8.10 With light easterly gradients, the surface easterly at North Front is gene - rally replaced by a light katabatic westerly during the night which may persist for several hours after sunrise.

8.11 With easterly gradients of 10 kn. or more katabatic flow into the Alboran Basin usually results in a strengthening of the surface easterly at North Front between 0100Z and 0300Z.

8.12 Probably resulting from the katabatic flow pattern in the Alboran Basin, surface easterlies at North Front for some hours before and after dawn tend to be from between NE and ENE. During the day, they veer to E-ESE as the sea-breeze component sets in.

8.13 Easterlies at North Front associated with an approaching trough or low from the west tend to decrease rapidly as soon as the 850-700 mb flow immediately east of Gibraltar backs to a direction within the sector 160-210 deg. if the mean speed in the layer is 20 kn or greater. In such circumstances cyclogenesis occurs in the Alboran Basin and decreases the pressure differential across the Straits.

8.14 Easterlies at North Front and in the Straits area usually increase rapidly if a flow of at least 30 kn at the 850-700 mb level over S.Spain veers between 040-080 deg. In such circumstances cyclogenesis occurs in the Gulf of Cadiz or west of the Moroccan coast between Cape Spartel and Casablanca. Similar effects are noted from between 100-160 deg over the Riff Mountains provided it does not extend much east of 5 deg. W. If it does, the cyclogenesis west of the Straits is offset by cyclogenesis in the Alboran Basin and the pressure differential across the Straits does not rapidly change.

9. Features of Westerly Winds at Gibraltar

9.1 At North Front, westerly surface winds are more variable both in speed and in direction than are the easterlies due to the topography to the west.

9.2 For similar magnitudes of the Ali-Cas PD westerly winds both at the surface and at levels up to 3000 ft are less strong than are the corresponding winds for easterly gradients. The explanation for this lies in the general topography of the area. With westerlies, there are alternative outlets for east-going air other than the Straits - the valley of the Rio Guadalquivir and the Taza Gap. For easterlies however, there is, west of a line from Almeria to Melilla, only one exit from the Alboran Basin - the Straits of Gibraltar.

9.3 The strongest winds at Gibraltar are from the southwest and are usually associated with NNW-SSW oriented fronts or troughs approaching from the west. In a narrow band some 20-30 nm wide ahead of such fronts or troughs the strongest winds occur. A useful indication of the magnitude of mean speeds and gusts which may be expected at North Front in such circumstances is the mean speed and gusts at Rota, Jerez and Seville as the front or trough approaches these stations. Of the three, Seville is usually the most reliable guide.

9.4 After the passage of a cold front or trough eastwards through Gibraltar with a veer of the upper flow to NW, westerlies in the Straits usually freshen as a lee trough forms in the Alboran Basin, often giving gale or near gale force south-westerlies in the Alboran Basin south of 36°N. In the Straits the strongest winds are to be found towards the African coast. (Fig 51 - Appendix B).

9.5 With due westerly low level flows over the Straits area, there is often a narrow band of comparatively stronger winds from the exit of the Straits extending eastwards along lat. 36 deg. N which may extend as far east as Alboran Island. North and south of this band, which is usually of the order of 5-10 nm wide, the westerlies are generally considerably lighter.

9.6 With even moderate WNW-NW gradients over S. Spain, strong NW'ly winds are frequently observed offshore during the night abeam of Malaga, Murcia and Alicante.

9.7 With light E'ly gradients (2000 ft winds at Gibraltar less than 10 kn) a katabatic westerly often of 5-8 kn/sets in at North Front below 500-800 ft during the night and may persist for several hours after sunrise.

9.8 In the summer months if the sea areas west of Tarifa are covered with a Sc layer with base 1000-1500 ft and tops 2-3000 ft whilst there is no cloud east of Tarifa, surface winds at North Front will generally be SW'ly and stronger than would be expected from the normal Ali-Cas relationship. In such circumstances, the Sc layer can often be seen to pour over the Algeciras hills and to dissipate

on the eastern slopes. The strength of the SW'ly at the airfield probably is from a lee trough effect in the Bay.

9.9 Gale force surface winds from between W and N are rare at North Front even with an Ali-Cas difference of arouhd 20 mbs.

10. Diurnal Variation of Surface Winds at Gibraltar

10.1 Easterlies

10.1.1 Direction. With surface easterlies of 20 kn or more, there is usually very little diurnal change of direction - even in summer when the southerly sea breeze component is at a maximum. Indeed such easterlies are noteworthy for their steadiness in direction.

10.1.2. With speeds less than 20 kn, the nocturnal direction tends to be around 060-080 deg., but during the day, there is usually a veer to between 110-130 or even further if conditions are favourable for sea-breezes (para 12).

10.1.3 As noted in para. 7.10 light easterly winds during the day at North Front tend to become light westerly during the night as a result of katabatic flow from the hills to the west.

10.1.4. Speed. Easterlies at North Front tend to reach a maximum during the forenoon and a minimum during the evening. A secondary maximum occurs after 0100-0300Z if previously winds have been in the order of 10-20 kn. Several writers, notably, Scorer (Ref. 7) have offered explanations for this, but the writer leans towards the simple explanation of the enhancement of the existing easterly flow in the Alboran Basin by the massive katabatic flow into the Basin after dark. If the original flow is at least 10 kn, there is no escape for the additional air to the east and the flow at Gibraltar and in the Straits must increase. If the original flow is less than 10 kn most of the excess air draining into the Alboran Basin is able to escape to the east and there is no nocturnal increase of the easterly at Gibraltar. Indeed this is often replaced by a light westerly due to the katabatic drainage from the Algeciras and Ronda hills (see para. 7.10).

10.2 Westerlies

10.2.1. Direction. Westerlies generally tend to back towards the southwest during the day and veer towards west during the evening.

10.2.2. Particularly in the summer months if the 2000 ft wind from the westerly quarter is under 23 kn, the surface wind at North Front will usually back to south-south-west (see para. 12).

10.2.3. With strong westerly or northwesterly winds (30 kn or over) at the 2-3000ft level, a lee trough is generated by the Algeciras hills resulting in a marked southerly component in the surface flow at North Front. In such circumstances considerable gustiness is often experienced, presumably due to wave motion.

10.2.4. Speed. Westerlies usually decrease during the night to less than would be predicted using the Ali-Cas diagrams. This decrease persists until 2-3 hours after sunrise.

10.2.5. When the situation described at 10.2.3 occurs, quite apart from the gustiness, a cyclical variation of mean speed over periods of 10-15 minutes can often occur.

11. Diurnal Variation of Winds at Rock Top Level

An investigation by Skelton (Ref. 8) of anemograms from an anemometer situated at Rock top level (precise position unknown but probably at Middle Hill) showed that easterly winds at that level have a semi-diurnal variation in the form of a symmetrical wave with a maximum at 0400Z and a minimum at 1600Z. The diurnal variation of westerly winds was found to be non-symmetrical having maxima at 0000-0100Z, at 1300Z and 2000-2100Z with a minimum at 0800-1000Z. Skelton was unable to provide an explanation for his findings. As far as easterlies are concerned, the writer suggests that the maximum at 0400Z is the result of the katabatic drainage into the Alboran Basin in the manner described at para 9.1.4. whilst the minimum at 1600Z is a result of the sea-breezes of the Alboran litto - ral and anabatic flow, particularly on the south-facing slopes of Spanish mount - ains bordering the Alboran Basin. In the case of the westerlies the times of the maxima and minima are less easily explained. It is possible that the maximum at 0000-0100Z results from katabatic drainage from the Algeciras and Ronda hills into the Bay of Gibraltar enhancing an existing westerly, and that the maximum at 1300Z is associated with the maximum of the sea-breeze component. It may also be possible that the maximum at 2000-2100Z is associated with the cooling of the surface layer and the decrease of the downward transfer of momentum from the layer at Rock top level, although one would expect the maximum to occur later in the night. The minimum at 0800-1000Z is also difficult to explain unless it is asso- ciated with nocturnal inversions rising to heights above Rock top level, but again one would expect the timing to be several hours earlier.

12. Sea Breezes

12.1 The sea breeze at Gibraltar has been investigated by Ward (Ref.9) and the writer (Ref.10). The main conclusions reached in these investigations were:-

12.2 There are two distinct types of sea breezes - one which occurs with light easterly gradients and another which occurs with light to moderate westerly gradients. The first type is essentially a part of the general sea breeze circulation of southern Spain, is usually from a SSE'ly direction and rarely exceeds 12 kn. The second is due to a locally generated vortex in the Bay of Gibraltar which results from the augmentation of an existing SW-NW flow in the Straits area by the normal sea breeze component west of Tarifa. The enhanced flow over the Algeciras hills results in the vortex in the Bay which gives rise to northerly winds over the western shore and southerly winds over the eastern side (See Fig.35

12.3 The onset and cessation of the westerly type of sea breeze is frequently quite sudden and the circulation can be vigorous giving winds from S-SSW of up to 20 kn with gusts to 30 kn. Another feature of this type of sea breeze is the rapid changes of air temperature as the sea breeze sets in or ceases, which, in the warmer summer months, can prove of significance for civil jet aircraft operations.

12.4 For sea breezes to occur the following conditions are required:-

(a) Skies must be clear or nearly so of cloud below 10,000 ft.

(b) 2000 ft wind speeds must be less than 23 kn if westerly, or 10 kn if easterly.

(c) There must be no surface or upper troughs within 100 nm of Gibraltar.

(d) The Ali-Cas difference must not exceed 2 mb for an easterly or 7 mb for a westerly.

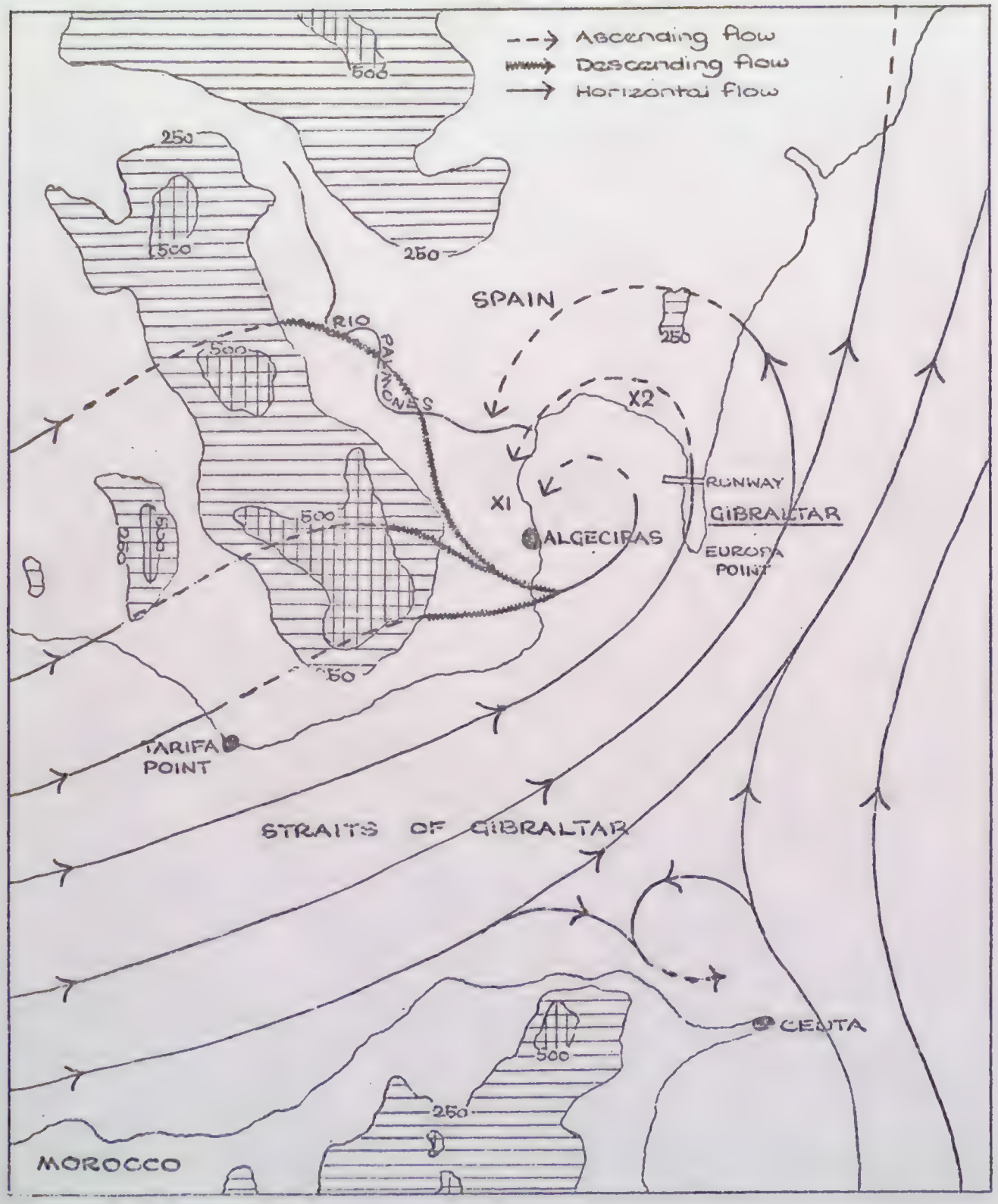
12.5 Other features of sea breezes are:-

(a) The majority of sea breezes occur with 2000 ft winds from the NW

(b) The strongest sea breezes are almost always associated with westerly gradients and the direction in such cases is usually SSW.

(c) Sea breezes associated with Ali-Cas differences near zero often appear at North Front as SSW'ly at the west end and SSE'ly at the east end of the runway ("split" wind). Such winds are however unlikely to exceed 15 kn and are predominantly below 10 kn.

(d) Low level stability and air-sea temperature differences do not appear to be significant factors in forecasting the incidence or strength of sea breezes.



Contours in metres
X1 - Smoke source (Factory)
X2 - Smoke source (Refinery at Guadarranque)

FIGURE 35 - THE SEA-BREEZE CIRCULATION IN THE VICINITY OF GIBRALTAR WITH WESTERLY GRADIENT.

(e) The majority of sea breezes commence, in summer, before 0900Z.

(f) Assuming other factors are favourable, the probability of sea breezes occurring have been assessed in relation to the Ali-Cas difference as follows:-

Pressure Diff. (mbs) Alicante - Casablanca		Probability of sea breeze at Gibraltar
+3 or more	(E'ly)	Nil
+ 2 to + 1	(E'ly)	Low
0 to - 6	(W'ly)	High
- 7	(W'ly)	Low
- 8 or less	(W'ly)	Nil

(g) The southerly flow associated with sea breezes at Gibraltar more often than not does not reach Rock top level.

(h) Sea breezes do not normally cause turbulence on the approach to runway 27 at Gibraltar. They can, however, cause a downdraught about ¼ mile from the end of runway 27 followed by an updraught over the threshold which may result in aircraft arriving with excess airspeed and delay in touchdown if the surface wind speed is 15 kn or more from SSW - a situation which is almost invariably associated with the westerly type of sea breeze.

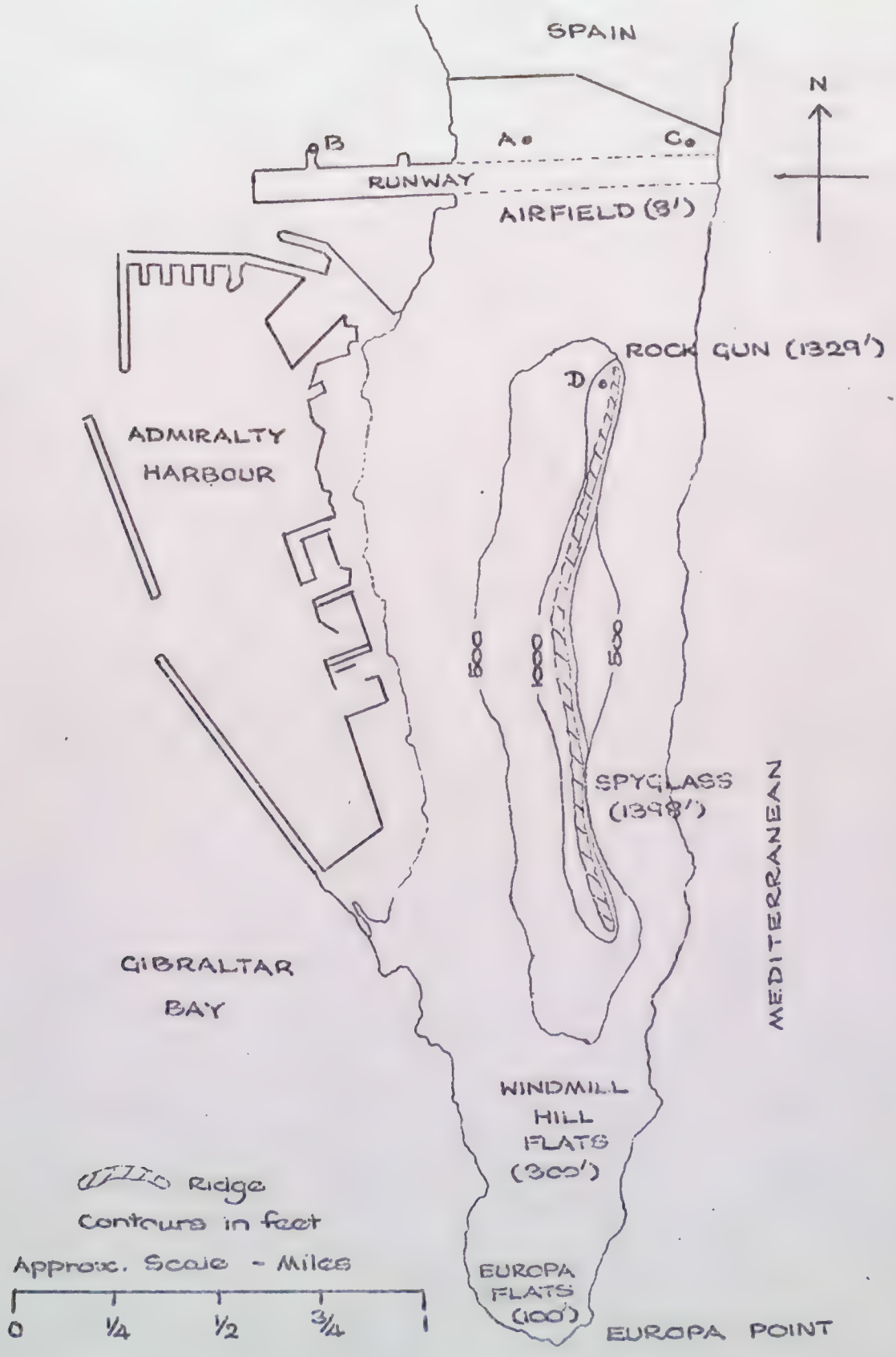
13. Variation of Wind Direction Along the Runway At Gibraltar. (Fig. 36)

13.1 An investigation was made by the writer (Ref 11) into differences in direction indicated by the three runway anemometers at Gibraltar and the results are given in Fig. 37.

13.2 It is readily evident that the indicated differences between the centre anemometer and both the eastern and western anemometers change appreciably as the general flow changes.

13.3 In the case of the eastern anemometer, the indicated direction always shows a veer on that at the centre anemometer both in summer and in winter. With the western instrument, there is a similar backing with due easterly winds in summer which is not evident but otherwise the general trend is for a veer on the centre direction.

FIGURE 36 - SKETCH MAP OF GIBRALTAR SHOWING LOCATION OF RUNWAY, ANEMOMETERS AND APPROXIMATE CONTOURS.



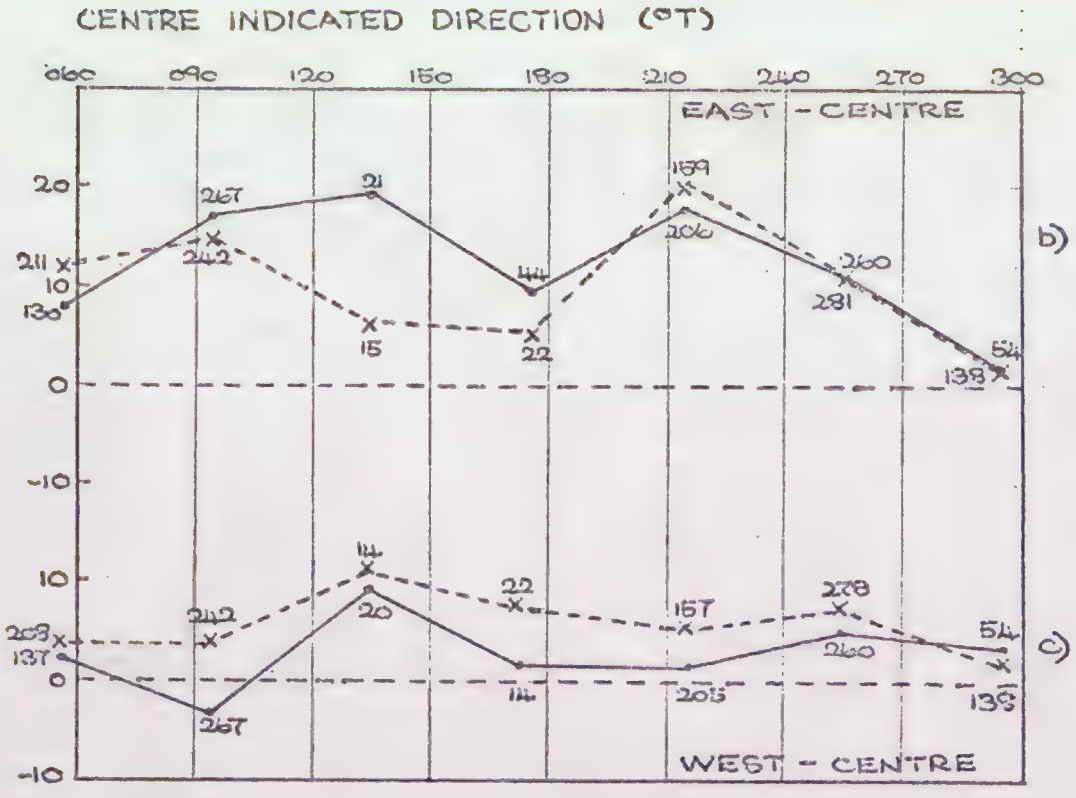


FIGURE 37 - Mean differences in direction between the a) Rock Gun, b) Eastern and c) Western anemometers and the Centre anemometer at Gibraltar.

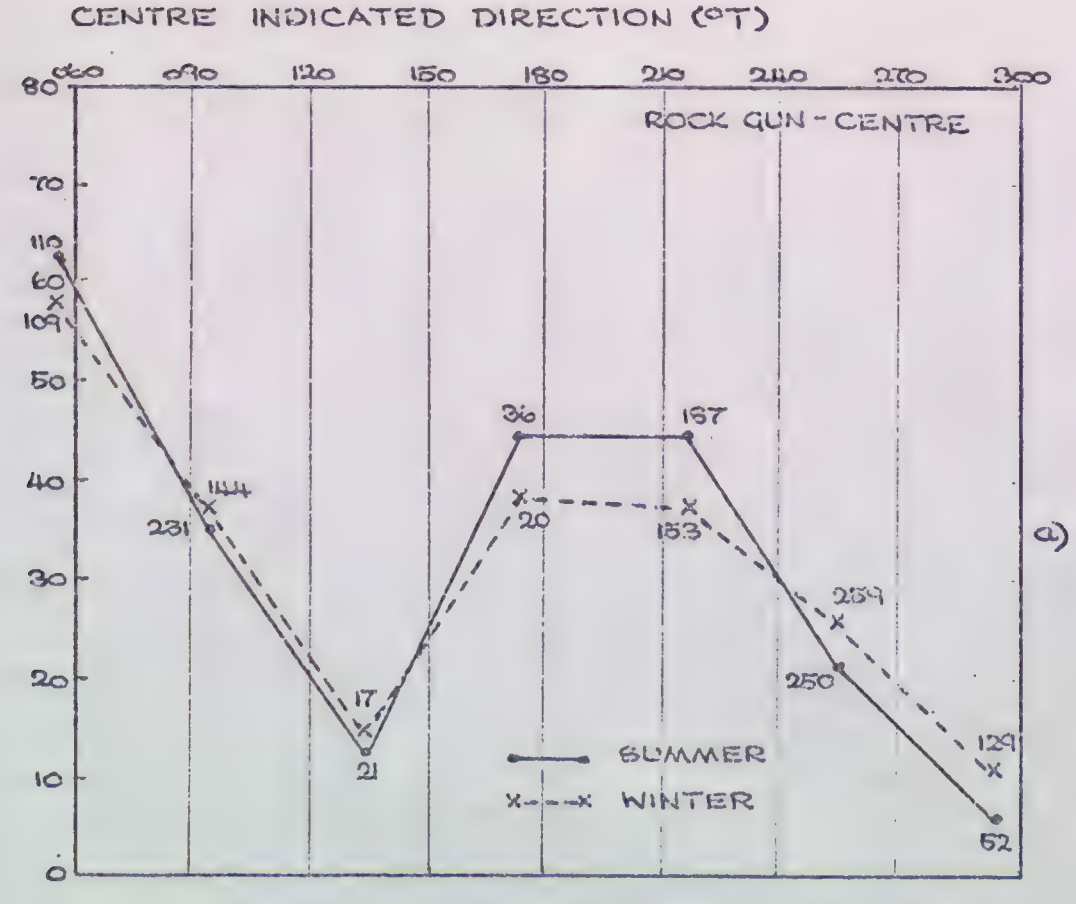


FIGURE 38 - Mean differences between Rock Gun and Centre anemometer directions.

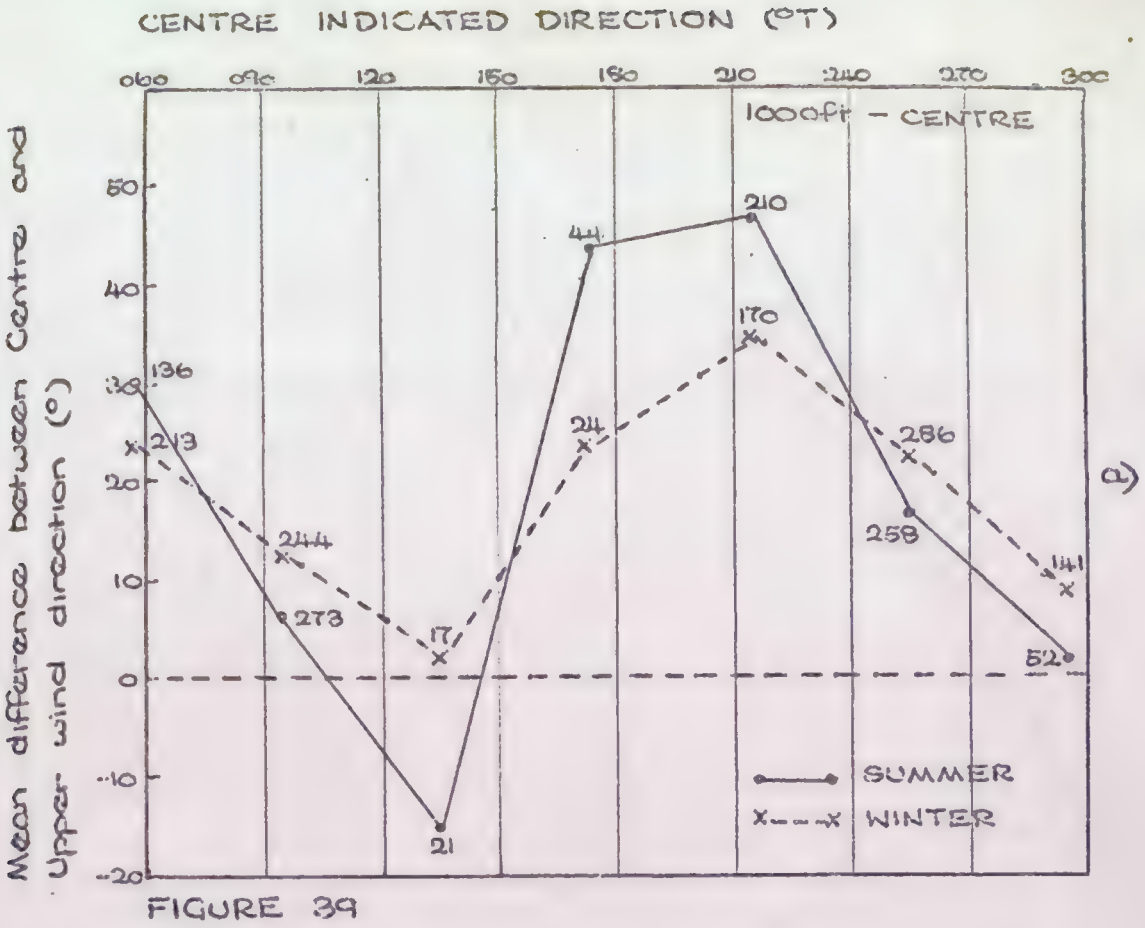


FIGURE 39

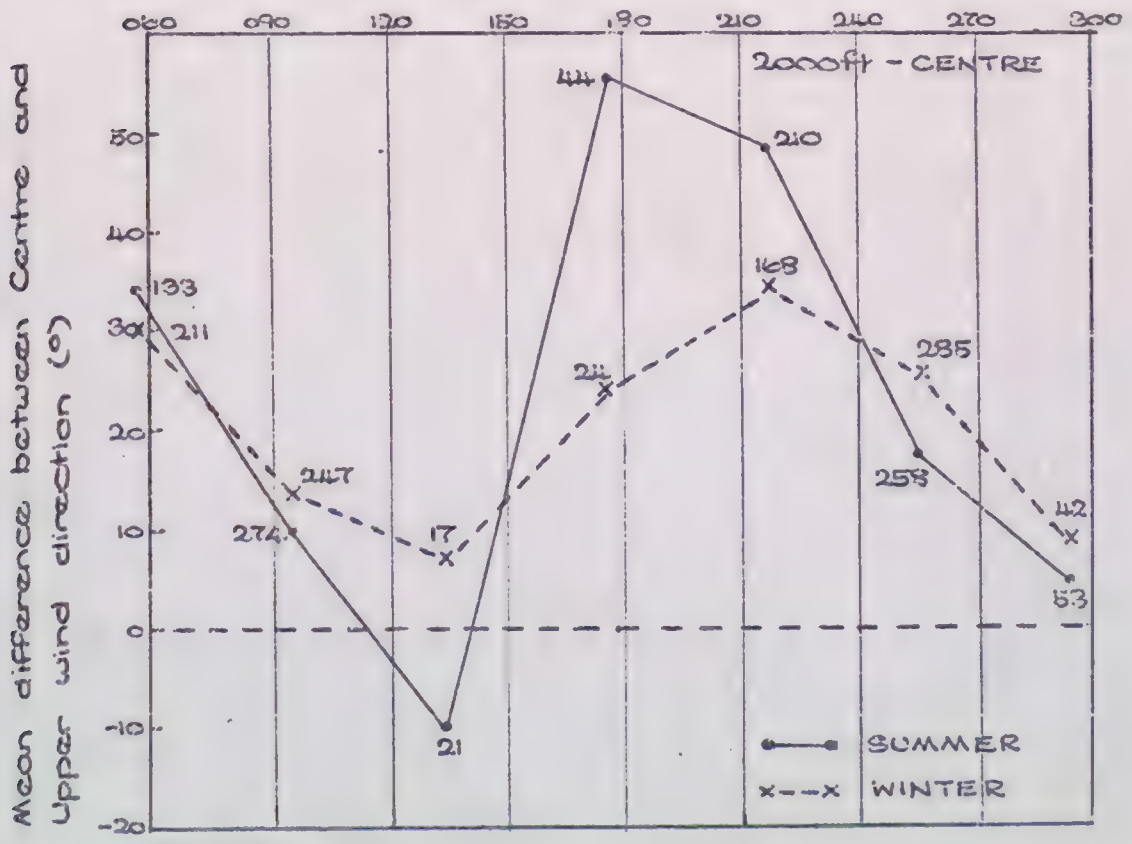


FIGURE 40

Mean differences in direction between a) the 1000ft radar wind and b) the 2000ft radar wind and the Centre anemometer at Gibraltar.

14. Differences in Direction Between Surface and Low Level Flow at Gibraltar.

14.1 Figs. 38 to 40 show the mean differences found by the writer (Ref 11) between directions indicated by the centre anemometer and those at Rock Gun and also the 1000 and 2000 ft radar winds. In all three cases it is evident that there are large variations in such differences as the general flow changes in direction especially with NE'ly and S-SW'ly winds.

14.2 Differences are greater in summer than in winter as a rule and serve to outline the effects of (a) low level stability and (b) wind speed on the magnitude of differences - inversions are a common summer feature and wind speeds generally higher in winter.

15. Forecasting Rules for Surface Winds at Gibraltar.

15.1 Most of the rules below are based on experience of forecasters based at Gibraltar in the period during and since World War II. Others have been suggested by Rota, for example, and other agencies. None are infallible and care must be taken to use them in the context of the current situation. Many will be obvious but bear reiteration for the benefit of newcomers to the Gibraltar forecasting scene - others are less so but have been found useful by some forecasters and as such are commended for consideration.

15.2 It will be appreciated from preceding paragraphs that, properly used, the best prognosticator of a change-over from easterlies to westerlies and vice versa at Gibraltar and in the Straits area is easily the Ali-Cas pressure difference. The timing of change-over and the values of wind speed associated with this parameter have already been discussed at length in para. 4.

15.3 Other forecasting rules for wind changes are:-

15.3.1. For Easterlies. Forecast a change to easterlies if:-

(a) A warm sector is expected to move from the southwest or west into the UK - usually the warm air must extend well north of 50°N on arrival in UK.

(b) An approximately N-S oriented upper trough extending to about lat. 35°S is expected to move E to reach 10°W.

(c) An upper ridge over NE Spain is expected to be replaced by an upper-trough - a useful guide in summer when gradients are weak in the Straits area.

(d) At OWS Romeo the 500-300 mb flow increases to 50 kn or more and veers to 010-020°. If the veer continues to about 040-050 the upper trough often extends SW allowing a westerly flow to become re-established in the Straits area.

(e) A cold pool over NW France is expected to move SW across Biscay and down the W. coast of Iberia.

(f) The Mistral sets in and the associated 500-300 mb flow over France and the Gulf of Lyons is oriented east of 360°. The time of onset of the easterly at Gibraltar is usually 24-36 hrs after the onset of the Mistral.

(g) A 500-300 mb flow of 50 kn or more orientated between 040-080° is expected to become established over Central and Southern Spain.

(h) An 850-700 mb flow of 25-30 kn or more orientated 130-150° is expected to become established over the Straits area and the Gulf of Cadiz. Note however that if such a flow extends eastwards towards the Algerian border -

cyclogenesis in the Alboran Basin inhibit the establishment of an easterly at Gibraltar.

(i) A cold front associated with a northerly flow over central and eastern Iberia is retarded in the west allowing the eastern portion of the front to swing west into the Alboran Basin, Such fronts are usually easily tracked down the east coast of Spain in winter but in summer may be difficult since there may be no accompanying weather. In this case they may be tracked by (a) wind changes at coastal and island stations - the arrival of the colder air usually kills an existing sea breeze (b) small dew point changes of 1-2°C, (c) the 850-700 mb isotherms.

(j) The Alicante-Oran pressure difference becomes positive - indicating an easterly flow into the Alboran Basin. Within 12-18 hours of this occurrence there may be sometimes - but not always - a change to easterlies at Gibraltar.

15.3.2. Forecast existing easterlies to decrease at Gibraltar if:-

(a) A cold front orientated NE-SW is expected to move SE across Biscay into NE Spain.

(b) An 850-700 mb flow of 20 kn or more from between 160-210° is expected to become established over the Straits and Alboran Basin.

(c) A surface low in the vicinity of Cape St. Vincent moves close to the western end of the Straits.

(d) A surface low near Cape St. Vincent is expected to move NNE into Portugal instead of moving east into the Gulf of Cadiz - a situation frequently associa - ted with a slow-moving and relaxing upper trough between 10-15°W orientated approximately NNE-SSW.

15.3.3. Forecast easterlies to increase if:-

(a) An upper ridge over NE Spain is expected to intensify.

(b) An approximately N-S orientated upper trough approaching Iberia is expected to sharpen and extend southwards of 35°S.

(c) An upper trough orientated NE-SW across S. Spain continues to tilt towards ENE-WSW and is expected to move into the Alboran Channel and Straits area.

(d) An 850-700 mb flow between 130-150° in the Straits and west Alboran Basin area is expected to increase to 25-30 kn or more.

15.3.4. WESTERLY WINDS: Forecast a change to Westerly winds if:-

(a) A NE-SW orientated and active cold front is expected to move SE across Biscay into the Bordeau-Toulouse area and to continue into the Gulf of Lyons.

(b) A cold front with waves becomes orientated approximately ENE-WSW from the Western Approaches to just north of the Azores so that the warm air does not extend north of 50°N and the high cell is displaced southeast to become centred west of Portugal.

(c) A frontal trough approaching Gibraltar from the west is expected to reach the western exit of the Straits - existing easterlies ahead of the trough will veer through SE and S to SW as the trough approaches.

(d) An upper trough is expected to move east of Gibraltar - in summer there is usually no associated surface front.

(e) A NW'ly jet with an axis just north of OWS Charlie is expected to extend SE across Biscay into the Gulf of Lyons.

(f) A cut-off low between the Azores and Madeira is expected to become stationary west of Madeira.

15.3.5. Forecast existing westerly winds at Gibraltar to increase if:-

(a) An upper trough is expected to pass east of Gibraltar.

(b) A WNW-NNW flow at the 850-700 mb level over S. Spain is expected to increase.

(c) A flow between 160-210° at the 850-700 mb level over the Straits and west of Alboran Basin is expected to increase to 20 kn or more.

(d) A deepening low over Biscay is expected to move SE into the Gulf of Lyons

(e) A NNW'ly jet over Ireland is expected to extend SSE towards the Pyrenees.

(f) A cold front moving south over Spain is retarded over the Gulf of Lyons but moves quickly south over and west of Portugal - winds usually back SSW-S and frequently reach gale force at Gibraltar as the western part of the front reaches the Straits area.

15.3.6. Forecast existing westerly winds at Gibraltar to decrease if:-

(a) An N-S orientated upper trough at about 30W is expected to move east towards Iberia.

(b) A strong NW-NNW'ly jet develops just east of OWS 'C'.

(c) A cold pool over UK or N. France is expected to move SSW towards Portugal

(d) A N'ly jet over France and NE Spain is expected to veer NE.

(e) A NW'ly jet over Biscay and the Gulf of Lyons is expected to move east.

16. Turbulence.

16.1 A considerable amount has been written concerning turbulence at and near Gibraltar, and three series of wind tunnel tests using a 1 : 5000 scale model of the Rock have been carried out to ascertain areas affected and the degree of turbulence which might be expected in different wind conditions. The first of these was carried out in 1933 by Field and Warden (Ref. 1), the second in 1963 by Briggs (Ref. 2), and the third more recently in 1976 by Cook (Ref. 3). Additionally the RAE investigated turbulence using a Meteor aircraft in 1963 (Ref. 22) and later an analysis of 944 reports by aircraft landing at Gibraltar in the years 1973-76 was made by McKay (Ref. 23).

16.2 Using the results of Cook's wind tunnel tests and the analysis of aircraft reports by McKay, Met O 9 have produced diagrams showing (a) areas affected by slight, moderate or severe turbulence and (b) the percentage frequency of moderate or severe turbulence associated with different wind conditions at Gibraltar, copies of which are available at the MMO.

16.3 Perhaps one of the major advances in the understanding of the nature of turbulence at Gibraltar is the concept of the Rock acting as a "lifting body" or aerofoil surface as described by Cook. With the "free wind" almost parallel to the spine of the Rock (orientated N-S) a narrow wake is shed across the runway containing no coherent vorticity - this is equivalent to a "lifting body" at zero incidence. With winds between 10 and 50 deg. to the spine, a horizontal roll vortex forms immediately behind the Rock - the equivalent of the bound vortex on a lifting body at moderate incidence. With winds between 50 deg and normal to the spine the flow is in a stalled condition and a long wide wake is shed with no coherent vortex structure but containing relatively slow moving eddies in a random fashion. These features are strikingly illustrated in the flow visualisation photographs at page 299 of Ref. 29 .

16.4 The experience of aircrews and forecasters at Gibraltar amply support the conclusions reached at Ref. 3 . For example, prior to the Spanish airspace restrictions, with strong southwesterly winds, many aircrews preferred to approach runway 27 from the NE - they experienced far less turbulence since they were flying along the vortex in more or less steady state downdraft or updraft conditions dependant on their actual position relative to the core until the final turn on to the runway instead of flying through the core on the straight-in approach advocated by the RAE study.

16.5 The wind tunnel tests carried out by Cook very clearly demonstrate the marked downdraft at about ¾ of a mile from touch-down in strong southwesterlies followed by a marked updraft in the last ½ mile of the approach which causes marked airspeed variations and usually results in aircraft arriving at the threshold with too much airspeed and occasional difficulty in landing.

16.6 With strong winds from SE-SSE which are infrequent but occasionally occur ahead of fronts, the vortex shed is less strong due to the asymetrical shape of the Rock and is in any case shed over the runway rather than on the approach and is thus no real hazard to aircraft unless overflying the runway at low level.

16.7 As previously stated with winds normal to the Rock, turbulence is random in nature and although severe updrafts and downdrafts may be experienced by one aircraft on base leg, frequently another following a few minutes later may report only moderate or slight turbulence.

16.8 With winds of the order of 30 kn or more (both easterly and westerly) fast moving rotating columns of spray rising to several hundred feet at times are raised in the lee of the Rock. With southwesterlies they are generated in the area of Catalan Bay and travel rapidly NE across the appraoch to runway 27. With easterlies they are generated in the Harbour and Bay, being particularly bad just outside the north entrance to the harbour, and very dangerous to small sailing craft. If due easterly winds are of gale force, in addition to the squalls in the harbour area, the area lying between the runway and the commercial mole is frequently affected by vortices streaming from the north face of the Rock which can produce very difficult conditions on the approach to runway 09 particularly on and just after the turn from base leg to finals. The gusts speeds associated with such squalls have been estimated by experienced observers to be often near twice the speed recorded at North Front at the same time.

16.9 Even with the improved understanding of the nature of turbulence at Gibraltar the forecasting of it remains a difficult problem. What, for example, does one use as a reference wind for entry into the diagrams derived from the wind tunnel tests? How do the areas delineated vary in size and position with different wind speeds? It is not possible to lay down hard and fast rules and limits for the purpose of forecasting turbulence, and each situation must be individually considered and all available evidence, eg Rock Gun winds, radar winds at the 1000 and 2000 ft levels, sea surface state, cloud patterns in addition to the runway anemometer readings and aircraft reports, if any, carefully sifted. It is also hoped that readings from the Europa Point anemometer will soon be available to assist

in the problem by supplying readings which will be comparatively free of the influence of the Rock for winds from SE thro' S to SW. However, as a first approximation Table III below is offered as a guide to the degree of turbulence which should be considered for directions and speeds limits shown. It must be emphasized however that the Table is intended to be used with deep flows from the directions indicated extending higher than Rock top level, with readings of the centre anemometer only and with the base of any low level inversions well above Rock top level. It does not apply to sea breezes, for example, the majority of which do not reach Rock top level. The sea breeze (W'ly type) usually gives an updraft at the threshold to runway 27 but no turbulence on the approach. The SE'ly type of sea breeze can be ignored for turbulence purposes since it is always too weak.

Centre Dirn. °T	Turbulence Mod.	Sev.	Centre Dirn. °T	Turbulence Mod.	Sev.
060	20 kn	28 kn	170	13 kn.	18 kn
070	21	29	180	12	18
080	22	30	190	13	18
090	23	31	200	13	19
100	21	28	210	14	19
110	18	24	220	14	20
120	16	21	230	15	22
130	14	19	240	19	23
140	13	18	250	19	26
150	13	18	260	21	29
160	13	18			

Table III:-Turbulence on final approaches related to wind speed and direction.

16.10 It may at first sight appear that the above values are not consistent with the wind tunnel tests particularly in respect of winds from a southerly direction. It must be remembered, however, that the centre anemometer readings are affected with winds from the southerly sector and may thus bear little relation to the true direction and speed of the flow affecting the Rock as a whole. It is worth re-emphasising, however, that the values given should not be used in isolation - all other sources of wind information and evidence have to be considered.

16.11 As a guide to the frequency of turbulence (occasional, frequent) perhaps the best guide apart from the percentage frequency diagrams produced by Met O 9, is to use 'occasional' at the lower limits and 'frequent' at the upper limits of each speed range.

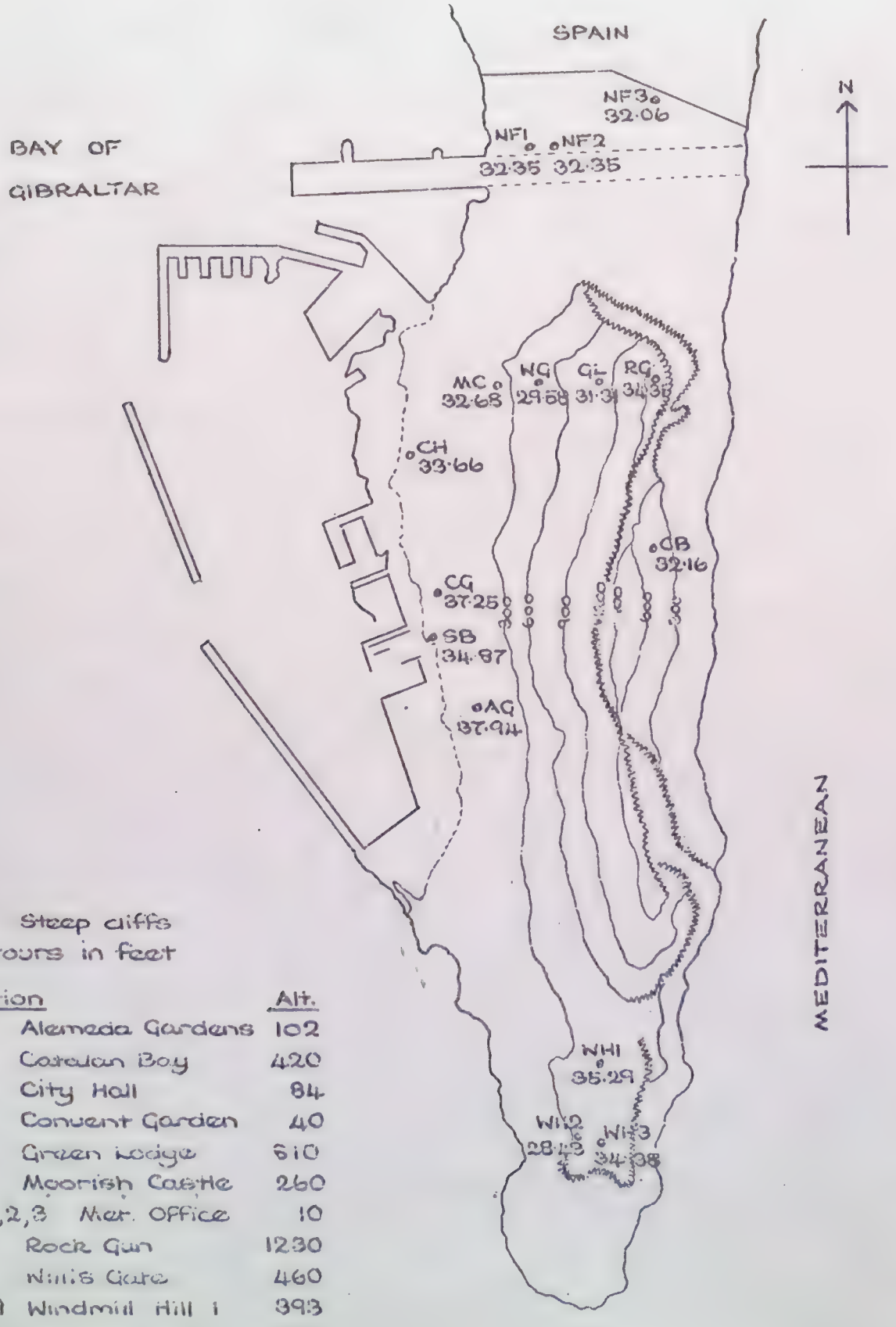
16.12 Another consequence of the Rock acting as a lifting body is that, with southerly or southwesterly winds there is frequently a fairly narrow band of strong southerlies at about 2-3 miles from touchdown which gives rise to marked starboard

drift on the approach and is often associated with moderate turbulence due to horizontal wind shear. The band of strong winds in this area is usually made visible by the effect on the sea surface.

16.13 Mention has been made earlier of the severe turbulence which can occur over Tangier Bay when low level easterlies are strong and orientated from between 100 and 120 deg. The reason for its severity probably lies in interaction of wave trains from the successive ridges of high ground lying between the Moroccan Mediterranean coast and Tangier.

16.14 Although pronounced wave effects are often observed in the Alboran Basin, there are few reported cases of severe turbulence associated with such conditions.

FIGURE 41 - Rainfall Stations and Averages, Gibraltar



KEY

wwww Steep cliffs

Contours in feet

Station		Alt.
AG	Alameda Gardens	102
CB	Catalan Bay	420
CH	City Hall	84
CG	Convent Garden	40
GL	Green Lodge	610
MC	Moorish Castle	260
NF1,2,3	Met. Office	10
RG	Rock Gun	1230
WG	Willis Gate	460
WH1	Windmill Hill 1	393
WH2	Windmill Hill 2	390
WH3	Windmill Hill 3	350
SB	South Bastion	51

SECT. B - RAINFALL

17. General.

Rainfall at Gibraltar is much influenced by the topography of the adjacent mainlands of Iberia and N.Africa and by the general configuration of the Straits area and the Alboran Basin. Apart from the modification of features such as surface fronts etc. convergence in the Straits area and orographic uplift make a significant contribution to the precipitation at and around Gibraltar. The reader is well advised to make a careful study of Chapters 1-3 of M.O.391 (Ref. 6) which deal with the effect of topography on air masses, fronts, and general weather systems of the Mediterranean area.

18. Climatological.

18.1 Fig. 1 (after Hurst - Ref. 30) shows that the annual rainfall at Gibraltar is, on average, higher than any other low level station in S. Spain or NW Africa, although Algeciras, Ceuta and Tangier follow fairly closely behind - a clear indication of the importance of topography.

18.2 Locally at Gibraltar average rainfall exceeds 30 ins. (762 mm) per year but there are quite considerable variations from one district to another. At Fig. 41 (after Hurst - Ref. 30) are given annual averages for a number of different rainguages on the Rock. It will be noted that rainfall on the eastern side is lower than in most locations on the western side.

18.3 Foster (Ref. 31) using the Alameda Gardens (AG) gauge as standard gives, for a period of five years from 1933-37, percentages of rainfall measured at the Moorish Castle (MC) Willis's Gate (WG) Green's Lodge (GL) Rock Gun (RG) and Catalan Bay (CB) gauges in various speed ranges of westerly and easterly winds and in calms. These percentages are given in Table IV below.

		West Wind			East Wind			Calm
Gauge	Force	1-2	3-4	5 and over	1-2	3-4	5 and over	
AG		100	100	100	100	100	100	100
MC		86	90	84	91	90	90	91
WG		83	81	63	90	89	86	91
GL		87	91	75	95	90	90	94
RG		90	93	88	94	95	80	95
CB		98	99	96	83	88	67	94

Table. IV :- Rainfall at various gauges as a percentage of that at Alameda Gardens in different wind speeds and directions.

18.4 No gauge records an excess of rain over that recorded at Alameda Gardens - the heaviest losses occur with the stronger winds and at intermediate gauge levels It is interesting that the Catalan Bay gauge records considerably less rainfall

than all but the Alameda Gardens gauge in easterly winds, particularly when strong, and considerably more with westerly winds. This suggests that the orographic contribution to rainfall amounts at Gibraltar is substantial.

18.5 As for the excess amounts recorded at the Alameda Gardens compared to the other sites, Foster suggests that with calms at or near sea level the wind at higher levels might well be Force 1 or more, probably reaching Force 3 at Rock Top level, causing losses at higher gauges due to eddying - a non-too convincing argument. The fact that the Alameda gauge shows an excess over the other instruments at all speeds and directions strongly suggests an exposure problem, perhaps a result of the much taller trees in the area than in any of the other locations higher up the Rock.

18.6 Significant rainfall at Gibraltar is generally confined to the period mid-September to mid-May when approximately 98 percent of the annual total usually falls. The wettest months are November to March during which an average of 77 percent of the annual total occurs.

18.7 The highest monthly total recorded since 1852 appears to be 633.2 mm (24.82 ins.) in November 1858. The exact position of the gauge is not known but it was probably South Bastion (SB on Fig. 41) at an elevation of 51 ft ASL.

18.8 The highest daily total since 1874 appears to be 293.9 mm (11.57 ins) recorded at North Front (NF 1) on the night of 30-31st January 1959. This particular fall caused severe flooding in the lower parts of the city - Queensway was under 3 ft of water and impassable to traffic for several hours.

19. Winter Rainfall (mid-September to mid-May)

19.1 Frontal Troughs

Sharp and comparatively fast-moving troughs with an associated surface cold front generally give substantial amounts of rain during their passage eastwards through the Straits area. Such troughs are usually orientated NNE-SSW with the 300 mb trough axis some 50-100 miles behind the surface front. Precipitation is usually in the form of a short period of moderate rain ahead of the surface front followed by heavy squally showers often accompanied by thunder which continue until the passage of the upper trough some 2-3 hrs later. With the passage of the upper trough there is a rapid improvement in the weather as the upper northwesterlies set in and very often the sky become completely clear of cloud.

Just ahead of the surface front there are usually strong and gusty southwesterly winds in this type of situation which veer more westerly on the passage of the front through Gibraltar. However, in the heavy showers between the passage of the surface front and that of the upper trough, there are likely to be temporary backings of the surface wind to the southwest and the permanent veer to west or north of west must await the passage of the upper trough through the station.

19.2 Non-Frontal Troughs

With broad slow-moving troughs orientated NE-SW with the 300 mb axis at 35N lying between 10W and 15W and having a broad NNE-NE flow to the rear, very subs - tantial amounts of rain can occur due to instability in the SW'ly flow over the Gulf of Cadiz and the Straits area. Although the trough may have been originally associated with a surface front, this will generally have passed east of Gibraltar or become diffuse and difficult to identify as a surface feature. The instability in the SW'ly flow is enhanced by convergence in the Straits area and orographic uplift over the Moroccan hills and heavy thundery showers can persist for long periods and result in large daily totals of rainfall.

19.3 Contraste Situations.

The development of the "contraste" has been described earlier (para. 6.4). The rainfall associated with it is usually continuous and moderate as long as the upper vortex lies in the vicinity of 8-10W. Such a situation can persist for several days and daily rainfall totals at Gibraltar can be very considerable. If the vortex moves closer to the western end of the Straits, rainfall tends to become more showery and can be very heavy at times. The majority of contrastes move east through the Straits with a rapid transition of the surface low from west to east of the Straits. During the passage of the upper vortex, on most occasions there are heavy thundery showers or thunderstorms at Gibraltar.

A much smaller proportion of contrastes move away to the southwest or south and the associated continuous rainfall at Gibraltar gradually eases, although there may be periods of several hours when almost moderate continuous rain continues to fall from altostratus cloud at Gibraltar, whilst to the north completely clear skies are plainly visible.

An interesting account of a contraste situation which gave prolonged heavy rainfall at Gibraltar and the surrounding area has been given by Hurst (Ref. 32).

19.4 Unstable NW'ly Airstreams.

Whilst NW'ly airstreams over S. Spain generally give rise to clear weather conditions at Gibraltar they can from time to time result in heavy showers or thunderstorms generated over Spain drifting SE to affect Gibraltar. They are, however, almost always very isolated and although they contribute significantly to the rainfall of the Cadiz province of S. Spain, their contribution to the Gibraltar rainfall totals is negligible.

19.5 Easterly Airstreams.

In the winter months, easterly airstreams are on occasions unstable to the sea temperatures of the Alboran Basin, and the resulting showers at Gibraltar can be quite heavy. Such a situation is most likely to occur a day or so after the onset of a particularly vigorous Mistral with a NNE'ly upper flow over the Gulf of Lyons. Less commonly it can occur with an E-W orientated upper trough lying from the Balkans to NW Africa.

A feature of the showers in such situations is that they generally begin during the night and die out during the forenoon - suggesting that katabatic drainage into the Alboran Basin materially assists in their formation by the effects of low level convergence.

Considerable rainfalls can occur at Gibraltar and over adjacent areas at the eastern end of the Straits with deep moist but comparatively stable easterlies having a long Mediterranean fetch - the upper air situation being generally an E-W trough from Morocco to the Gulf of Sirte with associated surface lows south of the Atlas and the mountain ranges of Algeria and Tunisia. If the strength of the low level easterly is of the order of 20 kn. or more, convergence in the western part of the Alboran Basin gives rise to the formation of an area of cloud which starts at 30-40 miles east of Gibraltar and ends abruptly just west of Tarifa. The cloud, the top of which is usually in the order of 6-7000 ft, smooth, and well below the freezing level, appears almost wall-like to aircraft approaching from the west. It is very dense and for long periods continuous moderate rain can fall at Gibraltar and the surrounding areas. Above the cloud, there is little in the

way of medium or high cloud except well to the south over the Riff and Atlas mountains.

19.6 Moist Westerly Airstreams.

Moist westerly airstreams of sub-tropical origin often reach the Straits area via the northern periphery of the Azores High when displaced well south in the winter season. Such airstreams can give considerable amounts or precipitation over the Algeciras hills to the west of Gibraltar despite the fact that the cloud tops are generally well below the freezing level. The rain does not normally reach Gibraltar unless the 2-3000 ft. winds are in the order of 25 kn or more, and then only in the few hours before and after dawn. Amounts, however, are almost always small.

In the Straits, however, due to convergence precipitation can occur all day and can be surprisingly heavy with visibilities being reduced to 1-2 km at times in rain.

20. Summer Rainfall (mid-May to mid-September)

20.1 From mid-May to mid-June and from mid-August to mid-September rain associated with frontal activity may be experienced at Gibraltar, but fronts are generally very weak and rainfall mainly light or at most moderate. Most of the precipitation in these periods is of a showery type and quite often associated with thunder - storms generated over the Moroccan hills in the afternoon which travel north in a southerly flow aloft to affect the Straits and Alboran Basin areas during the late evening and the night. These storms have been known to affect Gibraltar during the day however, and Pepper (Ref. 33) describes the occurrence of a very rare rainfall at Gibraltar around midday on September 9th 1949 when 97.2 mm were recorded in 105 minutes - a rate of approximately 1 mm/min.

From mid-June to mid-August frontal systems if they reach Gibraltar at all, are almost invariably too weak to produce precipitation. Any precipitation which occurs in this period usually arises from middle level instability cloud in a southerly flow aloft - and reaches the ground in the form of isolated large drops which are frequently heavily dust-laden.

21. Diurnal Variation of Rainfall at Gibraltar

21.1 The diurnal variation of rainfall in the period 1948-67 was investigated by Gilbert (Ref. 34) and his findings are presented in histogram form in Figs. 42 to 44.

21.2 In Fig. 42 the solid line shows for each hour the mean number of occasions per year in which rain (of any amount) was recorded. The dotted line shows the mean amount recorded per year in each hour.

21.3 The solid line shows a fairly sharp and symmetrical peak between 0800 and 0900 GMT and a minimum between 1800 and 1900 GMT. The dotted line also shows a similar trend although not quite in phase with the solid line.

21.4 In Fig. 43 similar data to that in Fig. 42 are given for different periods of the year - the values in brackets at the right being the total number of observations at each hour. In all periods the mean number of occasions per year for each hour follows the general trend of the annual values in Fig. 42 , but there are variations of intensity. Worthy of note is the fact that in the summer months the evening minimum tends to be earlier than in the winter months.

21.5 The mean rainfall per rain hour for the year and for different periods of the year is given in Fig. 44 . In general terms, in the wet season the highest intensities occur in the evening and the lowest in the early afternoon. In the dry season the highest intensities occur around midnight and in the early afternoon.

DIURNAL VARIATION OF PRECIPITATION - GIBRALTAR

NORTH FRONT 1948 - 1967

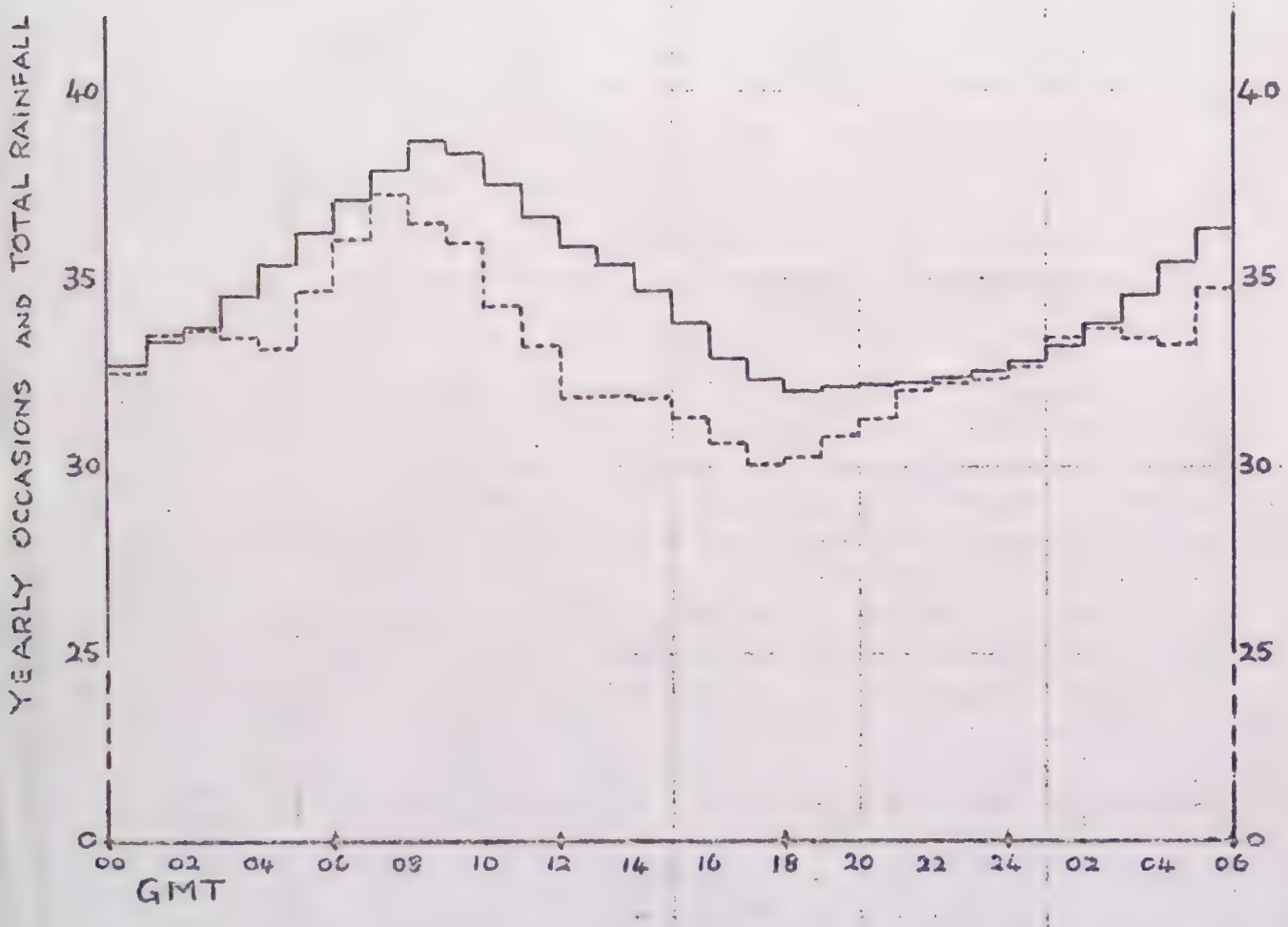


FIG. 42 ANNUAL

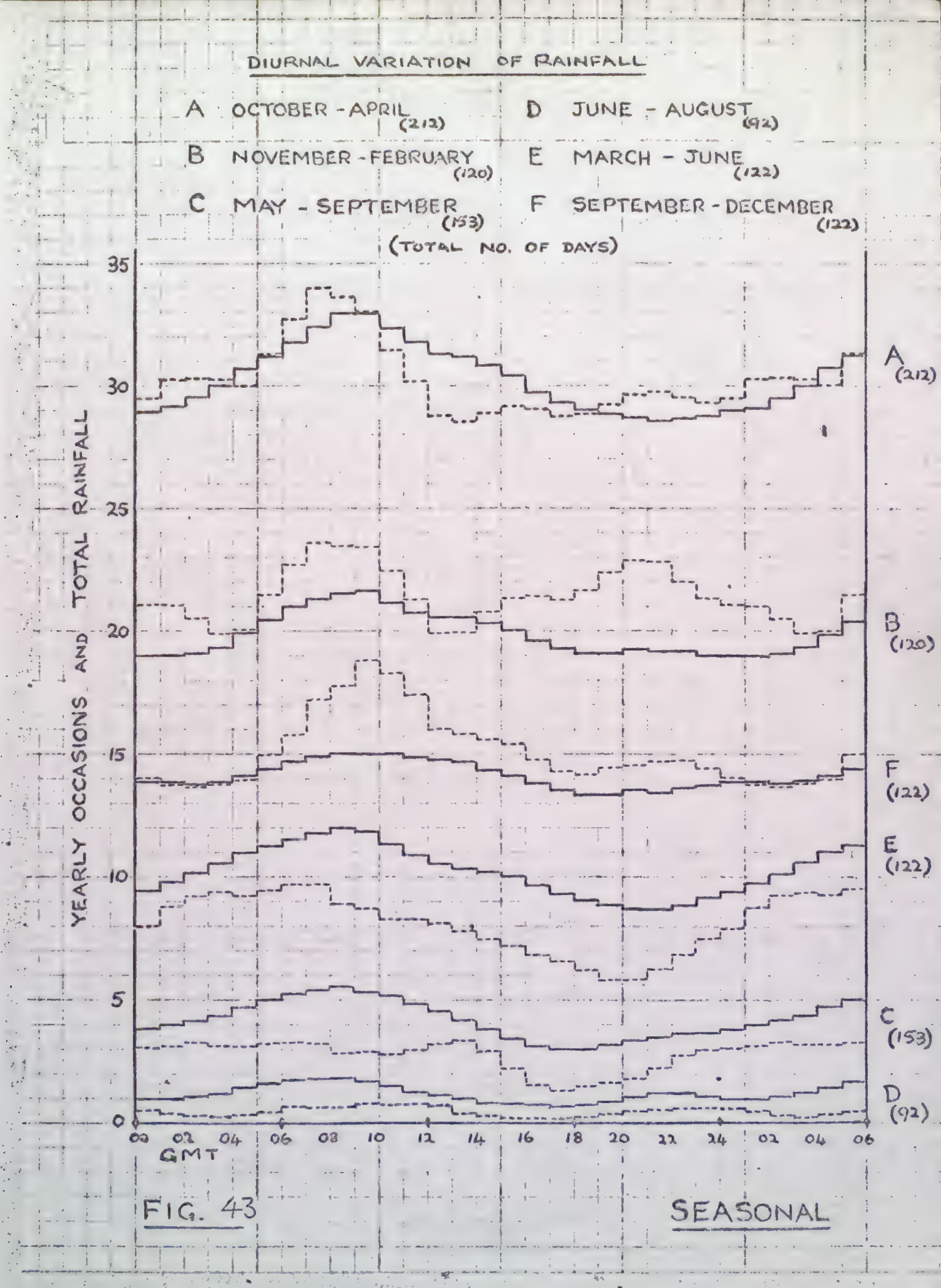


FIG. 43 SEASONAL

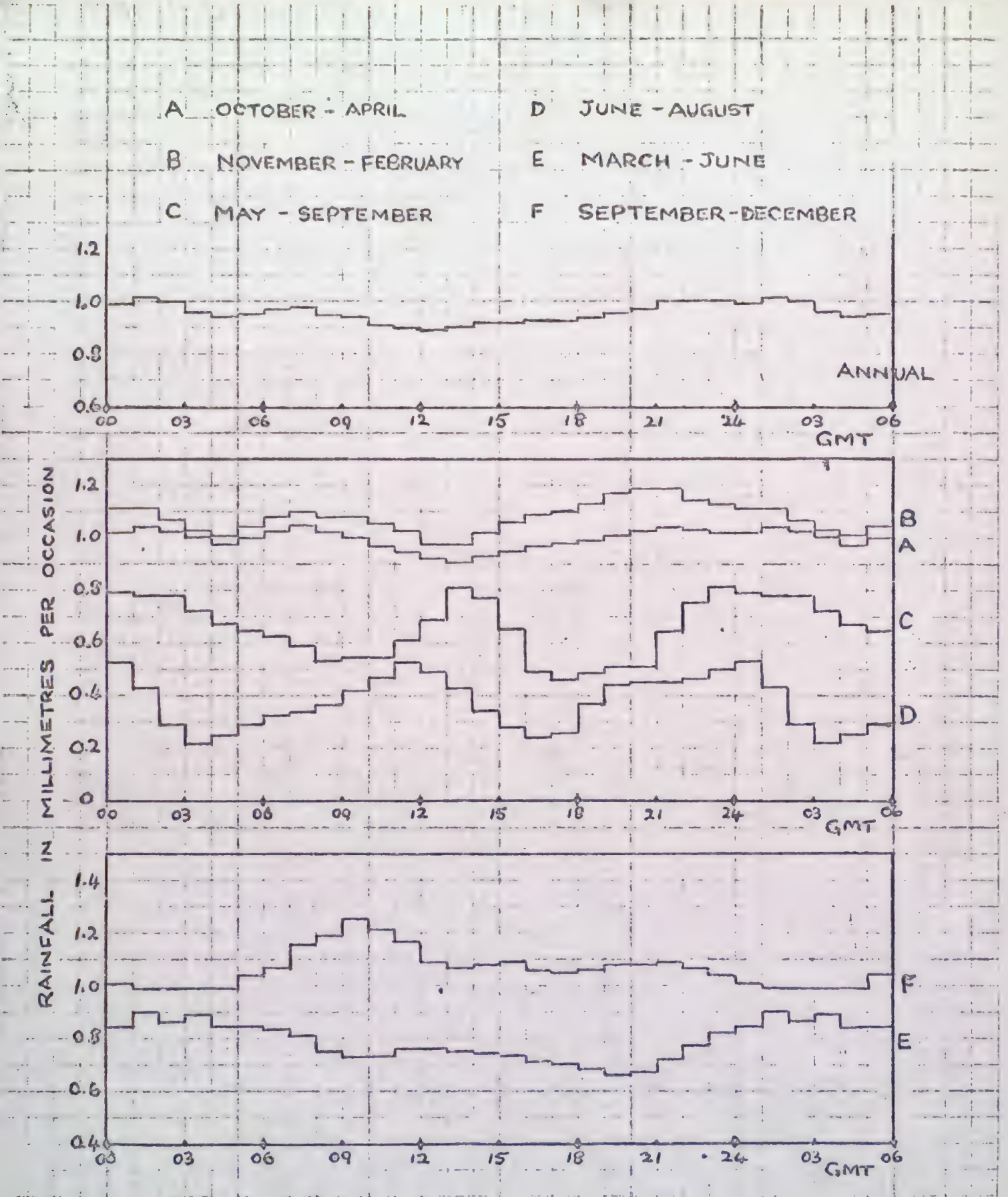


FIG. 44 MEAN RAINFALL PER RAIN-HOUR

FIG 45

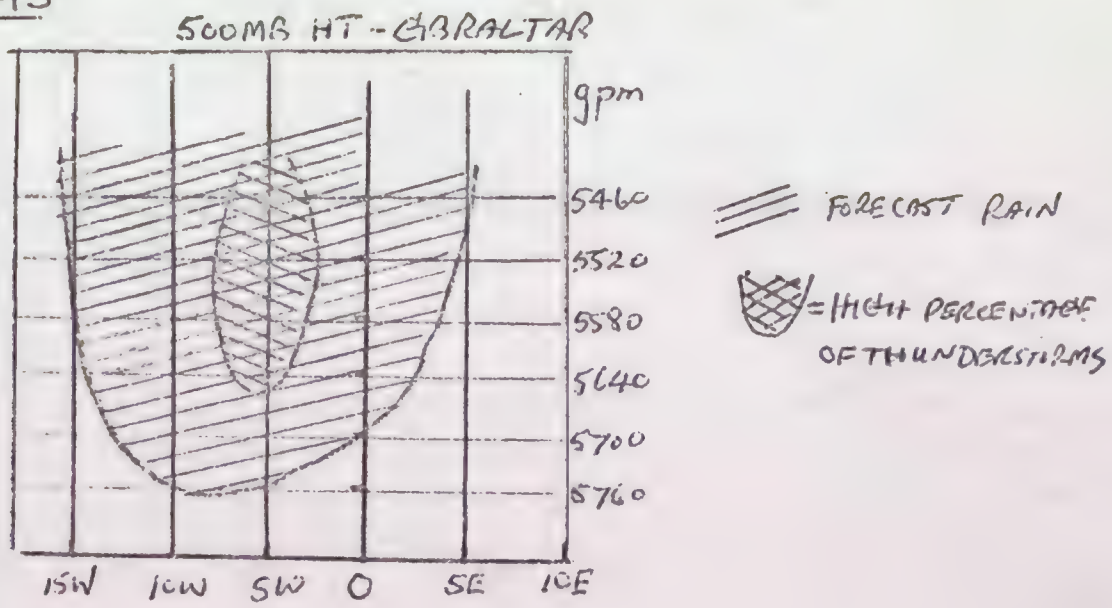


FIG 46

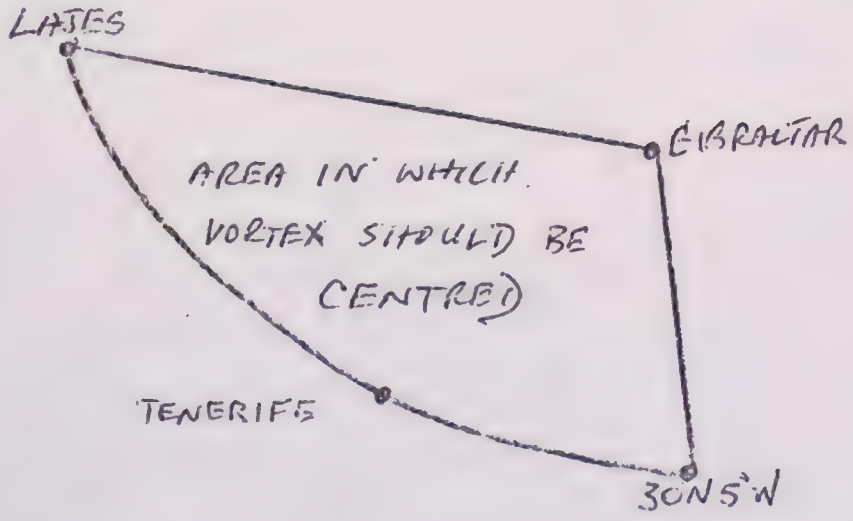


TABLE V

MEAN MONTHLY SURFACE PRESSURE - GIBRALTAR

JAN	FEB	MAR	APR	OCT	NOV	DEC
1020	1020	1019	1016	1017	1017	1018 MB

22. Forecasting Rules for Rain at Gibraltar.

22.1 Houseman's Rules. Based on data for the years 1969-71, Houseman (Ref.35) advocated the following rules which are used in conjuction with Figs.45-46 and Table V .

(a) Rule 1 - Trough Situation.

If the nearest 500 mb trough axis crossing 35 deg N when plotted against the Gibraltar 00Z 500 mb height falls in the shaded area of Fig. 45 , forecast Rain if the surface pressure at Gibraltar is below the monthly average or average and falling (see Table V). N.B. Plots falling within the central darkly shaded area show a high percentage of thunderstorms.

(b) Rule 2 - Vortex Situation.

If there is a 500 mb vortex at 00Z in the area shown in Fig.46 and the following factors:-

(1) Gibraltar 500 mb height equal to or greater than 5700 gpm - forecast NO RAIN
(2) " " 5580-5690 gpm and surface pressure below average or average and falling - forecast RAIN
(3) Gibraltar 500 mb ht. 5580-5690, and surface pressure above average or average and rising - forecast NO RAIN
(4) Gibraltar 500 mb ht. less than 5580 gpm - forecast RAIN

(c) Rule 3 - Ridge Situation.

(1) If the 500 mb ridge over the area is shallow ahead of a warm front approaching from the west - forecast RAIN ahead of the front

(2) If the ridge is in a warm sector with a waving cold front south of a line Lisbon-Madrid - forecast RAIN

(3) If the ridge is in a warm sector but all fronts are north of the Lisbon-Madrid line - forecast NO RAIN.

(d) Rule 4 - Unstable Airstreams.

(1) If the 500 mb flow is a strong one directed towards Gibraltar from OWS KILO (now ROMEO) and showing evidence of troughing forecast RAIN if the surface pressure is below average or average and falling

(2) If a fresh or strong easterly airstream has a veering trajectory across the Alboran Basin so as to increase the length of sea track, forecast showers if the air is convective to sea temperatures or more continuous rain if lift caused by convergence in the Straits is expected to push the cloud above the

0°C isotherm (Author's note:- This is not believed necessary - see Para 19.5)

(3) With a vortex to the NE (ie over Spain or W.Mediterranean) forecast showers if air is unstable to expected mainland temperatures and sufficiently moist to give Cu development.

(e) Houseman also makes the comment that rain was very likely with surface pressures below the monthly mean and unlikely when above.

22.2 Pepperdine's Rules. Based on data for a 10 yr period (1960-69) Pepperdine (Ref. 36) also proposed forecasting rules for rain at Gibraltar using only 2 criteria - surface pressure and the 500 mb wind.

Diagrams of using these rules are given at Figs. 47 and 48. The letters A, B, L and S have the following meanings:-

A - Surface pressure above the critical value for each month from Fig. 47 .
B - Surface pressure below the critical value for each month.
L - 500 mb wind speed below 40 kn
S - 500 mb wind speed above 40 kn

Having ascertained whether A or B and L or S applies at Gibraltar, enter Fig.48 which has to be used with the restrictions in notes 1-3.

22.3 Both Houseman and Pepperdine claim success rates of around 85 percent for their rules, but experience indicates that there is some doubt of the validity of these claims. Houseman's investigation refers to winter months only and his rules are based on very limited data. Pepperdine's limitation of parameters to two oversimplifies what is after all a rather complex problem. His rules have some validity in winter since he uses surface pressure as one of the predictors. His use of 500 mb wind speeds alone as the other is felt to be of little prognostic value. Perhaps he could have greatly improved his rules by the inclusion of 500 mb wind direction as well as speed. In particular his rules are of little prognostic value in the months of September and June.

Of the two sets of rules, those of Houseman are to be preferred, but both must be used with caution and forecasters would be well advised to consider other factors such as humidity aloft, surface dew points, the effect of topography, development, climatology etc before applying the rules at paras 22.1 and 22.2 above

22.4 In situations where a front which has given significant rainfall in Portugal and NW Spain is expected to move SE to affect Gibraltar it should be remembered that if the passage is to occur during the night, the probability of rain at Gibraltar is very much higher than if the passage is to occur during the day, particularly

FIG 47

Basic Criteria

(a) 00Z 500 mb Wind Speed under 40 kts = L
(b) 00Z surface pressure above critical (from diagram below) = A
(c) 00Z " " below " " " " =B

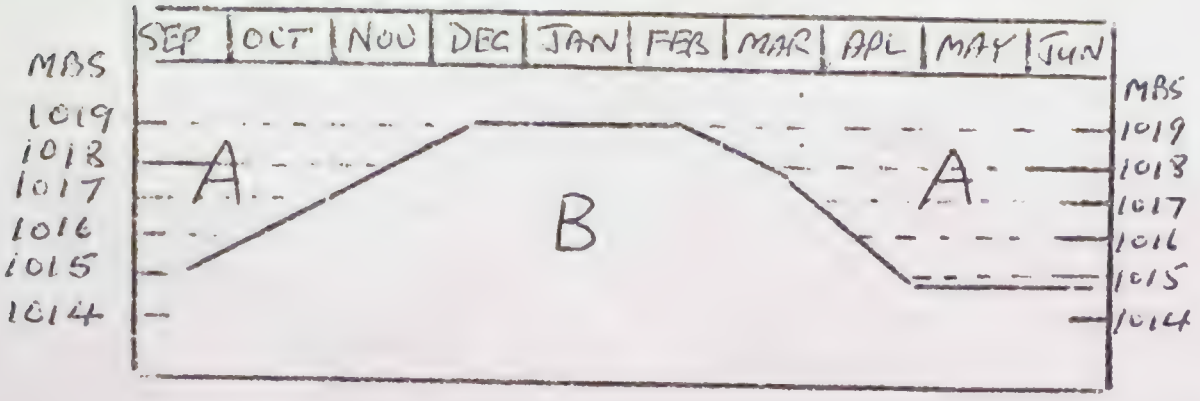
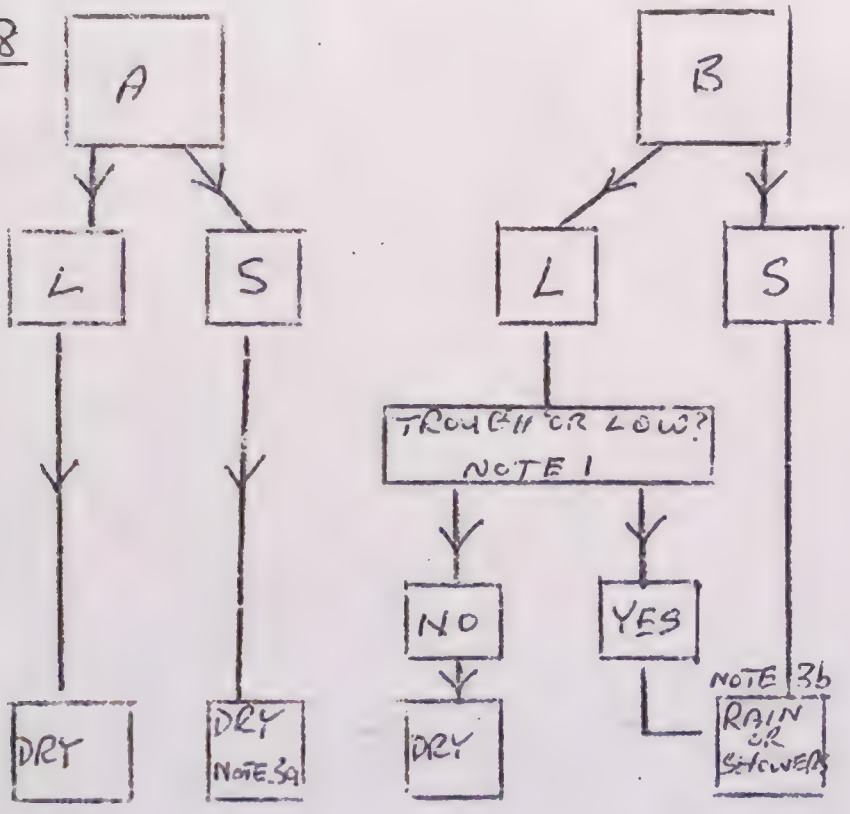


FIG 48



Notes.

1. Decide whether the centre of a 500 mb low will pass within 200nm or a 500mb trough(direction starting 180-280 deg and veer of at least 40 deg) will cross Gibraltar in forecast period
2. Marginal Cases. If the pressure is within 1 mb of critical value and/or the 500mb wind speed is around 40 kts then, unless any positive changes can be seen, the best forecast is one of persistence
3. Northwesterly Exceptions. (a) In AS cases when the wind is NW and is expected to persist strong NW for 24 hrs -forecast RAIN.

(b) In BS cases when the wind is now NW and is expected to persist NW(any speed) for 24 hrs. - any rain in the forecast period will be slight (3 mm or less)

FIGS 47-48 — PEPPERDINE'S FORECASTING RULES

SEE PARA 22.2

in the early evening. Very often and especially in the transitional months of April/May and September/October, there may be sighificant rain at places such as Rota and Sevilla, whilst there is none at Gibraltar if the passage takes place during the day.

22.5 As shown at Fig. 42 rain is much more likely to occur between 0500Z and 1000Z than at any other period of the day, and less likely in the early evening at all times of the year. This applies equally to frontal and non-frontal situations.

22.6 In situations where the upper flow behind a cold front approaching Iberia from the Atlantic is more westerly than northerly, such fronts tend to rapidly weaken south of 40 deg.N and are frequently too weak to produce any precipitation as they near and pass east of Gibraltar.

22.7 The use of satellite IR data only to judge the activity of fronts must always be approached with caution in latitudes south of 40 N - very often they have weakened to leave little else but a dense band of Ci which still looks very very active in the IR picture.

22.8 Ahead of cold fronts approaching from the west, rain is mainly moderate and continuous in nature. After the passage of the surface front it changes to a more showery character, and continues until the passage of the associated 500-300 mb trough. Thunder is frequently associated with the passage of the upper trough, particularly if sharp. The clearance behind the upper trough is usually rapid.

SECT. C - Visibility.

23. The best visibilities at Gibraltar generally occur with westerly winds and in the autumn and winter months. At all times of the year easterlies generally result in hazy conditions and in the months of July, August and early September, in particular, sea fogs are prevalent.

With the westerlies it is important to distinguish between air with a continental track and that with a maritime track. In the latter case visibilities are very good. In the former, industrial or dust haze can reduce visibility to around 15-20 km. With lighter westerly winds if fog has been widespread in the valley of the Guadalquivir overnight, especially in winter, a significant reduction of visibility can occur during the hours between dawn and midday at Gibraltar as the fog begins to lift and break up west of the Algeciras and Ronda hills.

Occasionally fog formed in the valleys of the Palmones and Guadarranque rivers which feed into the northern part of the Bay of Gibraltar drifts into the Bay in light westerly conditions but rarely affects Gibraltar. In the summer months sea fog may at times be advected into the southern part of the Bay by a southerly sea breeze setting in after a spell of easterlies but, again, this fog tends to disperse abeam of the detached mole and only very rarely affects the airfield.

Fog apart, easterly winds usually result in a reduction of visibility to between 5 and 10 km but in the winter months visibility may be considerably better if the air is unstable to sea temperatures. If the easterlies are strong and have been so for a day or two, visibilities can be particularly poor due to salt spray.

By reference to Sect. 38 it will be seen that sea fogs can occur in all months of the year at Gibraltar, although, as stated earlier, they are most prevalent in July, August and early September. Fogs at North Front and in the vicinity of Gibraltar have been fairly extensively investigated by a number of writers including Ward (Ref. 38) who found that 48 percent of fogs affecting North Front occurred after a change of wind from westerlies to easterlies - 30 percent occurred during a spell of easterlies and 20 percent occurred at the end of a spell of easterlies, whilst the remaining 2 percent were associated with heavy precipitation. He also found that although fog can occur at any time of the day, there is a maximum frequency about dawn and a minimum frequency during the afternoon. During the hours of darkness a light westerly katabatic flow from the Algeciras and Ronda hills often results in the airfield remaining clear whilst the sea fog remains just off the end of the runway only to cover the airfield shortly after dawn as the

katabatic flow dies out.

In the Straits sea fogs are usually first observed near the Moroccan coast - the coldest water generally being on that side of the Straits - see Sect. F. In the Alboran Basin due to the presence of the large clockwise gyre between Ceuta and Melilla (Ref 39) the favoured area for fog formation is again near the African coast from Melilla westwards to Tetuan and M'diq. McKay (Ref 40) has suggested that there is a secondary anticlockwise gyre east of Gibraltar which results in cold surface water moving south along the Spanish coast from Malaga to Gibraltar, and favours the formation of sea fogs which reach Gibraltar from a northeasterly direction. The katabatic drainage from the mountains of S. Spain into the Alboran Basin during the night is a large contributory factor in the formation of sea fogs in this area, and, it is suggested, explains way so many of the morning fogs affecting Gibraltar arrive from the north-east.

Fog is often associated with the passage of cold fronts - however weak - westwards through Gibraltar, a feature not confined to the summer months. Generally, however, such fogs are comparatively short-lived and soon become transformed into a layer of low stratus with a base of 6-800 ft with moderate visibility underneath.

As stated earlier, visibility in heavy rain may at times fall below fog limits, but very rarely below 3-400 metres.

With deep southerly flows in the summer months, visibility at North Front can be significantly reduced by dust from N. Africa. Although visibilities in such circumstances usually do not fall much below 10 KM, there have been some instances of visibilities of between 1000 and 2000 metres due purely to dust in suspension.

In Table VI below are given percentage frequencies of visibility 990 metres or below for each hour and each month based on an analysis of 1959-1971 data.

Time	Month											
GMT	J	F	M	A	M	J	J	A	S	O	N	D
00	0.2	0.5		0.3	0.2	0.5	4.2	5.7	2.1	1.2	0.5	0.2
01		0.3		0.5	0.2	0.3	3.7	5.7	1.5	1.0	0.3	0.5
02	0.2	0.3		0.5	0.2	0.5	3.2	5.5	2.1	1.0	0.3	
03		0.3		0.3	0.5	0.8	4.5	5.7	2.1	1.2		
04			0.2		0.5	1.0	4.0	5.5	1.3	1.7	0.3	
05	0.2	0.3	0.2		0.2	1.0	4.5	6.7	1.8	1.7	0.3	
06			0.2	0.5	1.0	2.3	4.5	5.2	2.6	1.7		
07		0.5	0.2	0.3	1.0	2.3	3.5	3.7	3.3	1.7		0.2
08	0.5	0.3	0.2	0.5	0.5	1.3	4.7	2.7	1.5	1.5		0.2
09		0.3	0.2	0.3	0.5	0.8	3.7	1.7	1.3	1.0		0.2
10	0.2	0.3			0.2	1.3	2.0	0.7	0.8	0.5	0.3	0.2
11		0.3				1.0	0.7	1.7	1.0	0.7		0.2
12		0.3				0.3	1.5	1.0	1.0	0.2		
13		0.3		0.3		0.3	1.2	0.7	0.5	0.5		
14		0.3	0.2	0.3			0.7	0.5	0.5	0.0	0.3	
15	0.2	0.3	0.2	0.3		0.3	0.5	0.2	0.8	0.0		0.2
16		0.3				0.3	0.5	0.2	0.5		0.3	
17		0.3				0.3	0.5	0.0	0.8		0.3	
18		0.5			0.2	0.3	0.2	0.2	0.8		0.3	
19		0.8				0.5	0.2	0.5	1.0			
20		0.5			0.2	0.8	1.0	2.5	1.0			
21	0.2	0.5			0.2	0.3	1.7	3.2	1.0	0.2	0.3	
22		1.1		0.3	0.2	0.5	2.0	3.2	0.5	0.2	0.3	
23		0.5		0.3	0.2	0.5	3.2	4.5	1.8	0.5	0.5	

Table VI :- Percentage frequencies of Visibility 990 metres or below at Gibraltar 1959 - 1971

SECT.D - CLOUD

26. Types of Cloud

26.1 General. Excluding frontal situations, with westerly winds low cloud is normally cumuliform with a tendency to become stratiform in the second half of the night. With easterly winds stratiform clouds predominate. In winter, however, there is a greater proportion of cumiliform cloud as air masses, particularly those with a comparatively short sea track can often be unstable to the sea temperatures of the Alboran Basin. In the summer months, the cloud associated with easterlies is usually in the form of low stratus which tends to complete cover during the night and to break up and disperse during the day. There may be left a banner of orographic cloud streaming from the Rock top - the well known "levanter" cloud - but on many occasions this also disperses during the afternoon only to reform in the evening if the easterly persists. At this season the base of the inversion or isothermal layers which are almost always present with easterlies are low thus limiting cloud tops to 1000-2000 ft as a rule. In winter, however, inversions are generally in the order of 3000-5000 ft and with the generally stronger easterlies and warm sea relative to air temperatures, the cloud is more often in the form of a Sc layer with a base of over 1000 ft than a low St layer. Being of greater depth than the low St layer, it also tends to be more persistent and frequently does not break at all during the day.

26.2 Large Cu and Cb. These clouds are much more in evidence in winter than in summer and are responsible for most of the annual rainfall totals. They are very frequently associated with the passage of cold fronts or upper troughs. Ahead of the surface fronts the cloud tends to be mainly stratiform - but there is a rapid change to a convective type which reaches maximum size and intensity just ahead of the 300 mb axis of the upper trough, giving heavy showers or thunderstorms. They are frequently encountered too in polar maritime airstreams returning from the southwest. Less frequently they form over Spain with unstable northwesterly polar maritime air and are advected towards Gibraltar. They are, however, rare in northerly flows of maritime arctic air over Spain. In the summer months although large but isolated, CBs are often plainly visible over Spain or Morocco, only rarely do they affect Gibraltar.

26.3 Medium cloud. Excluding frontal systems, medium cloud of orographic origin is frequently observed at Gibraltar. In the case of such

clouds, those associated with northerly flows over Spain are almost always lenticular with bases well above 8000 ft. Frequently a spectacular display of plate-like clouds at three or four levels is observed to the north-east of Gibraltar - a phenomenon known locally as the "Contessa del Viento". Medium clouds associated with southerly or southwesterly flows over the Riff Mountains of N. Africa are mostly lenticular in winter, but in summer Ac Castellanus predominates. This usually begins to appear at levels above 10,000 ft during the late morning and increase in development and amount to reach a maximum during the early part of the night, after giving spectacular displays of lightning in the Alboran Basin area east of Gibraltar. In the right circumstances, such Ac Castellanus can develop into high level CB with bases down to 5000-6000 ft and give rise to thunderstorms which, however, occur most frequently east of Gibraltar and only rarely affect the station in the summer months. With strong westerly winds at comparatively low levels, wave clouds generated by the Algeciras and N.African hills from time to time remain stationary over Gibraltar with bases at about 5000-6000 ft. but are not operationally significant. Wave clouds with southeasterly flows over the N. African mountains are very uncommon, and mostly occur in the winter months.

26.4 High Cloud: Ward (Ref. 47) has discussed orographic cirrus cloud at Gibraltar. He states that it is relatively frequently observed especially in the summer months - this is probably because low and medium cloud amounts in these months are generally much less than they are in winter (see para 28). He also states that marked diurnal variation of the amount of such cloud appears to occur. The cloud first appears around dawn, increases to 3-4 oktas during the forenoon, disperses during the afternoon, reappears in the early evening and at times increases to 6 oktas only to disappear after dark. Ludlum (Ref 48) suggests that the afternoon minimum may be due to the effect of increased instability near the ground reducing the high-level wave disturbance. Ward suggests, conversely, that the increased stability near the ground at night would magnify the high-level disturbance, thereby favouring a maximum frequency of cirrus during the night.

27. Cloud Bases. Cloud bases below 1000 ft are comparatively rare with westerly winds and are usually associated with frontal passages or very heavy showers, and are generally of short duration. Of much more operational significance are the low stratus and lifted fog patches associated with the easterlies, especially in summer. Houseman (Ref.46) carried out a most useful analysis of cloud amounts and bases associated with wind speeds and directions at Gibraltar, and this clearly shows that with easterly winds in summer of 6 kn or less, about 15 per-cent of cloud bases are below 500 ft, whereas for the same months the value for westerlies is about 2 percent. In winter the corresponding values are about 6 percent for easterlies and 1 percent for westerlies. For winds between 11 and 16 kn about 12 percent of bases are between 500 ft and 1000 ft and about 75 percent 1300 ft or more with easterlies both in summer and in winter. For the same speed range with westerlies about 7 percent lie in the range 500-1000 ft in winter and virtually nil in summer. In winter 86 percent and in summer 99 percent of bases are 1300 ft or above in this speed range.

28. Diurnal Variation of Cloud Base and Amount.

The lowest cloud bases follow the normal pattern of being most frequent during the hours of darkness and immediately after dawn. In the case of a change over from westerlies to easterlies, however, especially in summer the base of any associated low stratus is often lowest for the few hours after the formation of the stratus.

The average cloud amount at 03, 09, 15 and 21Z for each month in the years 1964-73 are given in Table VII below :-

Time	J	F	M	A	M	J	J	A	S	O	N	D
0300	3.8	4.1	3.8	3.2	2.4	2.3	1.9	2.3	2.9	3.5	3.7	2.9
0900	4.9	5.0	4.7	4.2	3.9	3.4	2.7	3.0	2.7	4.5	4.9	4.1
1500	4.9	4.9	4.6	4.0	3.3	2.4	1.2	1.6	3.1	4.0	4.6	3.9
2100	3.8	4.1	3.6	2.8	2.7	2.1	1.4	1.7	2.5	3.6	3.9	3.1

Table VII :- Average cloud amount at 03, 09, 15, and 21Z at Gibraltar.

In the majority of months the maximum cloudiness occurs around 09Z and the minimum at 21Z.

The average number of days with clear (presumably 0-2 oktas) and cloudy (presumably 6-8 oktas) skies at Gibraltar for each month of the year is given in Table VIII below (extracted from Ref. 6 page 340)

Clear	J	F	M	A	M	J	J	A	S	O	N	D	YR
Clear	7	5	4	6	7	12	17	15	9	7	4	6	99
Cloudy	8	5	9	5	3	1	4	1	2	5	8	7	54

Table VIII :- Average number of clear and cloudy days at Gibraltar (1945-1956)

More useful information on clouds at Gibraltar is to be found in pages 241-243 of Ref. 46

SECT E - SUNSHINE

29. Monthly Averages and Local Variations.

Monthly averages in the period 1947-1976 for North Front are given in Sect.38 together with the highest and lowest totals observed in the period.

The only sunshine record for Gibraltar other than North Front is that for Windmill Hill Flats for the years 1938-1947. Hurst (Ref.51) has discussed the variations of sunshine observed and to be expected at various locations on the isthmus due to exposure and the distribution and diurnal variation of the "levanter" cloud. He also gives at Table 2 of Ref.51 the average monthly and yearly cloud amounts for selected stations in S. Spain and N. Africa which shows that Gibraltar is the most cloudy station in the area, and the sunshine probably lower than any other low level station within many miles except possibly in the Ceuta/Tangier area. He concludes also that the sunniest part of Gibraltar is the southern tip since this is least likely to be affected by cumulus or "levanter" stratus. It certainly becomes evident in lavanter conditions that the area south of and including the RN Hospital and the area north of the runway are the most favoured locations for sunshine with the Catalan Bay area a good third.

SECT F - Oceanography.

30. Movement of Surface Waters near Gibraltar.

Fig. 49 (after McKay - Ref.40) shows the major eddies which are thought to exist in the vicinity of Gibraltar. There are, of course, many minor eddies and the reader is referred to Refs 52 and 53 for details of these.

The presence of the major gyre east of Ceuta is amply confirmed by infra-red evidence (Ref 39). Although there may be some doubt of the gyre depicted as lying northeast of Gibraltar there is little doubt of the existence of a mainly south-going current along the Spanish coast from Malaga to Gibraltar which is of cold water origin. Ramsey (Ref 55) considered together with Mommsen (Ref 39) that the source of this cold water was upwelling due to offshore westerly winds. As McKay points out, however, for a major portion of time in the summer months the coastal winds in this area are predominantly southeasterly due to the land - sea temperature contrast which lasts far into the night and any katabatic offshore flow is limited to a very few hours in these months. If upwelling takes place along this stretch of coast in summer therefore offshore winds are unlikely to be the sole cause.

31. Sea Surface Temperatures.(SSTs) Near Gibraltar, SSTs are subject to large local variations in short periods of time due to the mixing of Atlantic and Mediterranean waters as a result of current inflow at and near the surface into the Mediterranean., outflow at depth through the Straits, tidal streams, and drift currents arising from wind flow through the Straits and in the adjacent sea areas. Upwelling due to the topography of the sea bed also makes a major contribution to such variations. In the Straits area, a particularly important upwelling area exists near Tangier, and is probably to a large degree responsible for the generally colder water to be found on the southern side of the Straits.

32. Variations of SSTs near Gibraltar. For a considerable number of years the RAF Marine Craft Unit at Gibraltar have made SST measurements at various points near Gibraltar. These have been studied by Ramsey (Ref 54) and McKay (Ref 40). The latter gives, in addition to monthly mean values of SST in the years 1962-76 examples of changes of SST with wind regime in the Straits area. After prolonged spells of westerlies SSTs, at least in the warmer months of the year, fall considerably, whereas with easterlies the reverse occurs. There are, however, occasions when

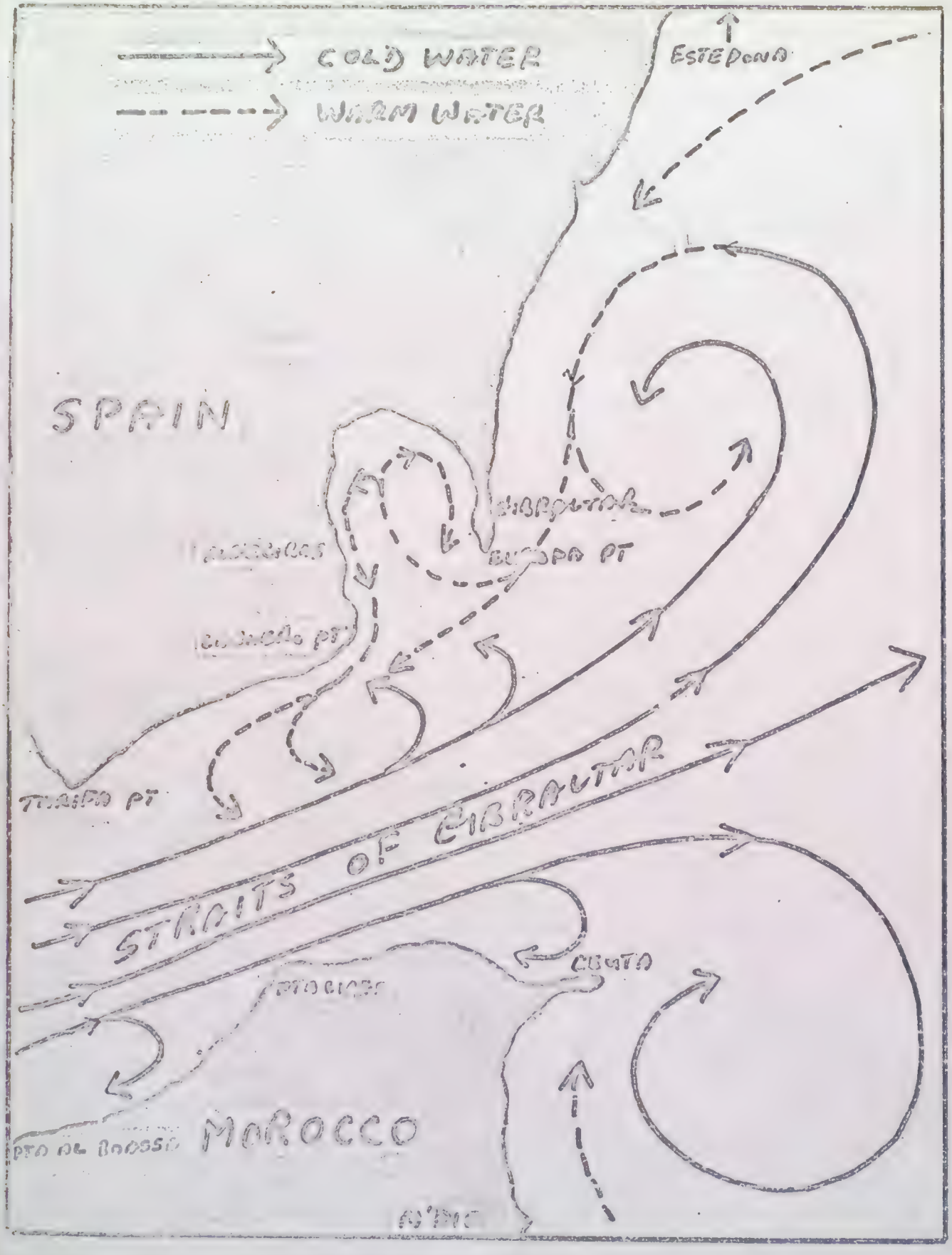


FIG 49 :- SURFACE WATER FLOW IN THE VICINITY OF GIBRALTAR - MAJOR EDDIES

the onset of westerly winds brings warmer water into the Bay than previously existed with the easterlies and vice versa and these are discussed in Ref 40.

In summer local variations of SSTs may reach nearly 5°C in 24 hrs depending on wind regimes and strength. In the winter months when temperature contrasts between Mediterranean and Atlantic waters are much less or even reversed from the normal summer pattern, local variations above 1°C are comparatively rare.

33. Sea Conditions.

In the Straits when surface flows due to current and tidal stream may reach nearly 5 kn eastgoing and 2 kn westgoing, with contrary winds particularly the easterlies, very short seas with remarkably steep wave fronts are frequently experienced and can cause much difficulty to small craft - a fact reflected in the design of local Spanish fishing boats which are characterised by their high Phoenician type prows. In areas where there is substantial upwelling, tidal races, or overfalls, for example near Punta Malabata just east of Tangier and off Cape Spartel, seas involving contrary winds and tides can be particularly dangerous.

On a high proportion of the time, swells in the Straits and western Alboran Basin are either short or average. If, however, there are northerly gales affecting the Mediterranean coast of Spain north of Cape de Gata, longer heavy swells extend westwards to the Straits and result in heavy surf in coastal areas of Spain, Gibraltar and Morocco exposed to the east. Similar conditions also occur with the levante - the winds of long fetch blowing from NE or ENE towards the Spanish coast.

Strong easterly winds in the Straits often continue westwards in a comparatively narrow band to 7 - 8°W, and seas associated with this situation can be very rough if it has persisted for some time.

A particularly dangerous sea can result in the same area with a "contraste" situation where easterly winds from the Straits become confluent with the south - westerlies in the Gulf of Cadiz to give gale force southeasterlies between Cape Trafalgar and the Spanish-Portuguese border. With the appropriate tidal conditions seas in this area can become violent and dangerous even for comparatively large ships, especially close to the tidal races and overfalls which extend SW from Cape Trafalgar to Bajo Aceitara.

With strong northwesterly gradients over S.Spain and the Alboran Basin, gale force winds with very rough seas are common-place south of latitude 36°N and extend

further east along the Algerian and Tunisian coasts.

The Bay of Gibraltar is well protected from long fetch Atlantic swell and to a slightly lesser extent from easterly swells. With easterly winds, sea conditions in the Bay are almost always slight. With persistent strong westerlies it may become choppy but wave heights rarely exceed 1 metre. With strong and persistent southwesterlies, however, it can become quite rough in the Bay with wave heights of 2-2½ metres. In the Admiralty harbour, persistent southwesterlies can cause difficulty for small craft moored in the destroyer pens at the northern end of the harbour since the southern entrance is open to the southwest for this area.

Very difficult and choppy sea conditions are often experienced by small craft rounding Europa Point with a combination of adverse tides and contrary winds of 15-20 kn or more and the contribution of upwelling which occurs due to the sub-surface reefs which extend SE from the Point.

SECT G - MISCELLANEOUS

34. Thunderstorms are predominantly a feature of the autumn, winter and spring months. In these months they are mostly associated with the passage of cold fronts, upper troughs or cold pools eastward through Gibraltar. A lesser pro - portion occur as isolated events in unstable polar maritime air returning from the southwest whilst a very much smaller proportion occur in unstable north - westerlies over Spain and are advected towards Gibraltar. Thunderstorms at Gibraltar are rarely associated with deep easterly airstreams though they can occur with surface easterlies in "contraste" situations when the upper trough or cold pool is in the process of passing from west to east over Gibraltar.

In the summer months, the few thunderstorms which do occur are almost always generated in a southerly flow over the Riff and High Atlas mountains and advected northwards, but the majority pass to the east of Gibraltar. The first precursor of these storms is the appearance of Ac Castellanus during the day which gradually develops into high level CB during the course of the early evening. The storms usually break out towards dusk and may last well into the night, giving vivid displays of lightning but not a great deal of precipitation at Gibraltar. A good example of this type of situation has been documented by Ward (Ref.58).

With winter storms, precipitation is often of tropical intensity with visibilities reduced to 400-500 metres or so. Cloud bases are, however, rarely below 1000 ft except in the heavier storms associated with frontal systems when patchy low St may occur at 400-500 ft. In such storms, surface winds are fre - quently very gusty and often present considerable difficulty for aircraft land - ing at Gibraltar if from a southwesterly direction.

35. Hail is comparatively uncommon, unknown in the summer months, and most likely, as with thunderstorms, in autumn and winter.

36. Snow or Sleet is very uncommon. In February 1954, however, substantial amounts of snow fell over the mainland adjoining Gibraltar Bay and the Rock itself, resulting in the blocking of the road from Algeciras to Tarifa for the best part of the day. On the Rock, however, the snow melted soon after falling.

37. Waterspouts are not infrequently observed in the Straits area and are, of course, associated with very unstable conditions mostly with southwesterly or westerly airstreams. Hurst (Ref. 59) documents the occurrence of waterspouts observed by an RAF aircraft to lie in a line up to 2 miles apart. At least 4 were seen about 60 miles west of the Straits. On this occasion the airstream was an easterly in the Straits up to at least 5000 ft but the flow southwest

/of

of the Straits was mainly southerly and very unstable to sea temperatures with virtually a dry adiabatic lapse rate from the surface to 1700 ft. The day was one of very heavy rain at Gibraltar, and from Hurst's description it is obvious that it was a normal contraste situation with unstable moist southwesterly mid-level air overlying moist low level easterlies.

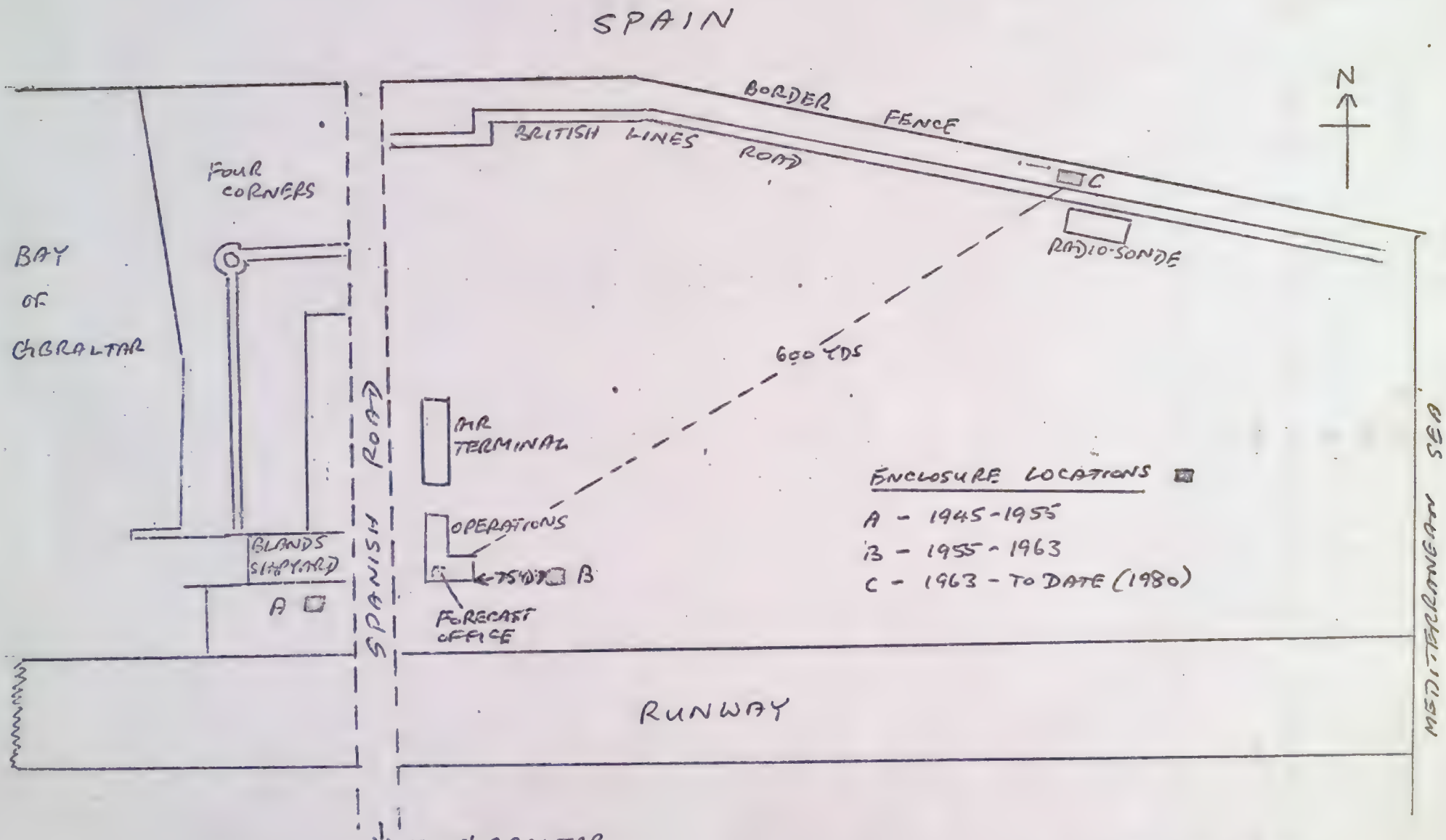


Fig 50 :- SKETCH MAP SHOWING LOCATIONS OF ENCLOSURE 1945 - TO DATE
(NOT TO SCALE - POSITIONS APPROXIMATE)

38. Climatological Data - North Front 1947-76

Published climatological data for Gibraltar refer in the main to comparatively short periods of observations at Windmill Hill Flats and at North Front. The observing station at Windmill Hill Flats was opened on 1st December 1935 and closed on 31st December 1947. The station at North Front was opened on 1st November 1942. In May 1945, the enclosure was moved to a position just south of Blands Shipyard (Position A on Fig.50) with the Forecast Office adjacent to it. In 1955 the Forecast Office moved into the present Operations building on the east side of Spanish Road, and the enclosure moved to a position 75 yds east of the Operations building (Position B). In March 1963, it was again moved to a new position adjacent to Radio-Sonde on British Lines Rd., close to the border fence (Position C) and approximately 600 yds ENE from the Forecast Office.

Although Table IX contains data from Positions A, B and C, at least it covers 30 years of observations from the area of North Front.

39. Additional Climatological Data

Tables X a to Xℓ contain data gleaned from a variety of sources published and unpublished. Published sources are Met O 617c - Tables of Temperature, Relative Humidity and Precipitation of the World Pt III (1958), MO391 - Weather in the Mediterranean Vols I and II (1962), and MO 446b(1) - Weather in Home Waters and the North-Eastern Atlantic Vol II Part I (1944).

Unpublished sources include locally produced annual weather summaries, monthly statistical returns, a Met O 3 investigation in the case of wet bulb data, and copies of rainfall records for Gibraltar supplied by Met O 3.

Wherever known, dates and/or year of occurrence of highest and lowest values are given. For the published data, these are generally not available locally.

APPENDIX A – REFERENCES & BIBLIOGRAPHY

Note: All items marked * are unpublished papers or notes available in the MMO Library – Gibraltar.

Sect. A – Winds & Turbulence

1. Field J.H. and Warden R. – A survey of air currents in the Bay of Gibraltar 1929–30 Geophys. Mem. London 7. No.59 1933.

2. Briggs J. – Airflow around a model of the Rock of Gibraltar Met O Sc paper No.18 1963.

3. Cook N.J. – Aircraft Flight Paths at RAF Gibraltar BRE Special Investigation No.18 1963.

4. Ward A. – A note on Surface Winds at North Front Gibraltar 1953. *

5. McKay W. – Surface and Low Level Winds in relation to surface pressure differences between Casablanca and Alicante 1977. *

6. – Weather in the Mediterranean – MO 391 – Vol I HMSO 1962.

7. Scorer R.S. – Airflow near the Surface in the region of Gibraltar 1944 . *

8. Skelton P.N. – Diurnal variation of wind velocity at Gibraltar in easterly and westerly winds. *

9 Ward A. – Sea Breezes at North Front Gibraltar – Met Rep. No.14 1954.

10. McKay W. – The Sea Breeze in the vicinity of Gibraltar – 1975 *

11. McKay. W. – Anemometer and low level wind readings at Gibraltar – 1977. *

12. Gordon A.H. – Surface and Upper Winds at Gibraltar *

13. Scorer R.S. – Mechanical Aspects of the Airflow through the Straits. *

14. Anon – Cross Wind Investigation *

15. Anon – Wind Peculiarities at Gibraltar and in the vicinity. *

16. Scorer R.S. – The Importance of Lapse Rate to the airflow near the surface in the region of Gibraltar. *

17. Ashford O.M. – Effective Height of the Anemometer at Gibraltar *

18. Gray F.R. – Some Notes on Forecasting Surface Wind at Gibraltar. *

19. Anon – Variation of the Surface Wind along the runway at Gibraltar *

20. Hancock SFJ - Some notes on the effects accompanying the onset of easterlies at Gibraltar. *

21. Scorer R.S. - Mountain Gap Winds - A study of surface wind at Gibraltar R Met Soc QJ 78 - 1952.

22. Burnham J. and Spavins C.S. - Gusts on the Approaches at Gibraltar Airfield RAE Tech Rpt. N 65099 - 1965.

23. McKay W. - Turbulence on the Runway Approaches at Gibraltar. *

24. Anon - Factors leading to turbulence at North Front Gibraltar. *

25. Melvin Capt.W.W. - Wind Shear (low level) - Air Clues APL 1975.

26. Houseman J. - A Note on Surface Winds at Gibraltar. *

27. Anon - North Front Surface Winds - Some Operational Aspects. *

28. Hampson L. - Airfield Operational Problems - Feb 1973 *

29. Cook N.J., Coulson B.H., McKay W. - Wind Conditions around the Rock of Gibraltar - Journal Indust. Aerodynamics 2 1977/78 289-309

Sect. B - Rainfall

30. Hurst G.W. - A statistical survey of rainfall at Gibraltar Aug.1956 *

31. Foster H.E. - Rainfall at Gibraltar Sept. 1942. *

32. Hurst G.W. - Prolonged heavy rain at Gibraltar 20-26 Nov.1955. Met. Mag.

33. Pepper J. - Very rare rainfall at Gibraltar Sept. 9th 1949. *

34. Gilbert J.T. - Diurnal variation of rainfall - North Front May 1968. *

35. Houseman J. - Forecasting Rain at Gibraltar for 24 hr. period. *

36. Pepperdine E.C. - Forecasting Rain at Gibraltar. *

37. Anon - Precipitation at Gibraltar. *

Sect. C - Visibility

38. Ward A. - Fog at North Front Gibraltar - Met. Mag.81 1952 *

39. Mommsen D.B. - The effect of wind or sea surface temperature gradients in the Straits of Gibraltar and Alboran Sea *

40. McKay W. - A Note on sea surface temperatures near Gibraltar. *

41. Anon - Some factors affecting the formation of sea fog at Gibraltar. *

42. Gilbert J.T. - Incidence of poor visibility July-Aug. *

43. Ward A. - The effect of radiative cooling on the formation of sea fogs and low stratus near Gibraltar. *

44. Anon - Fog days 1947-53. *

45. Gordon A.H. - Occurrence of fog in the Straits of Gibraltar. *

46. - - Weather in Home Waters and NE Atlantic NO 446b(1) (Appendix on Gibraltar) HMSO 1944.

Sect. D - Cloud

47. Ward A. - Orographic Cirrus Cloud at Gibraltar. *

48. Ludlam F. - Quart J R Met Soc Vol.78 p 554.

49. Houseman J. - Percentage Frequencies of amounts and heights of low cloud at Gibraltar. *

50. - Weather in the Mediterranean MO391 Vol.II HMSO.

Sect. E - Sunshine

51. Hurst G.W. - Variation in sunshine at Gibraltar - Met. Mag.87 1958

Sect. F - Oceanography

52. - Notes on currents and tidal streams in the Straits and around Gibraltar (extracted from W. Coasts of Spain and Portugal Pilot). *

53. - Tidal flow in Gibraltar Harbour (charts supplied by Chart Supply Officer HM Dockyard Gibraltar). *

54. Ramsey B. - Summer sea surface temperatures at Gibraltar - Marine Obs. Vol. XXV No.207 HMSO.

55. Ramsey B. - Influence of Winds and Tides on Summer Sea Temperatures in the Gibraltar area. *

56. - Straits of Gibraltar - Surface and Sub-Surface water movements - HD 386 Hydrographic Dept. 1944.

57. Maidens A.L. - Currents and Tides in the Straits of Gibraltar 1944. *

Sect. G - General

58. Ward A. - Unusual August Weather over S. Spain and Portugal Met. Mag. Vol.82 1953.

59. Hurst G.W. - Waterspouts off the Straits of Gibraltar - Met. Mag.

60. Hurst G.W. - Variation in pressure at Gibraltar - Met. Mag.87 1958.

61. Hurst G.W. - Nature of diurnal variation of pressure at Gibraltar. *

62. Hurst G.W. - A brief history of Meteorology in Gibraltar

63. Anon - Sea fitness at Gibraltar. *

64. Gordon A.H. - Relative humidities in east and west winds at Gibraltar *

65. - Aeronautical Climatology Summary - Gibraltar. *

66. Sharp F.A. - Harbour area winds in an easterly situation *

67. Anon - Note on average weather conditions in Gibraltar. *

68. Atherton WSA - Extreme temperatures at Gibraltar. *

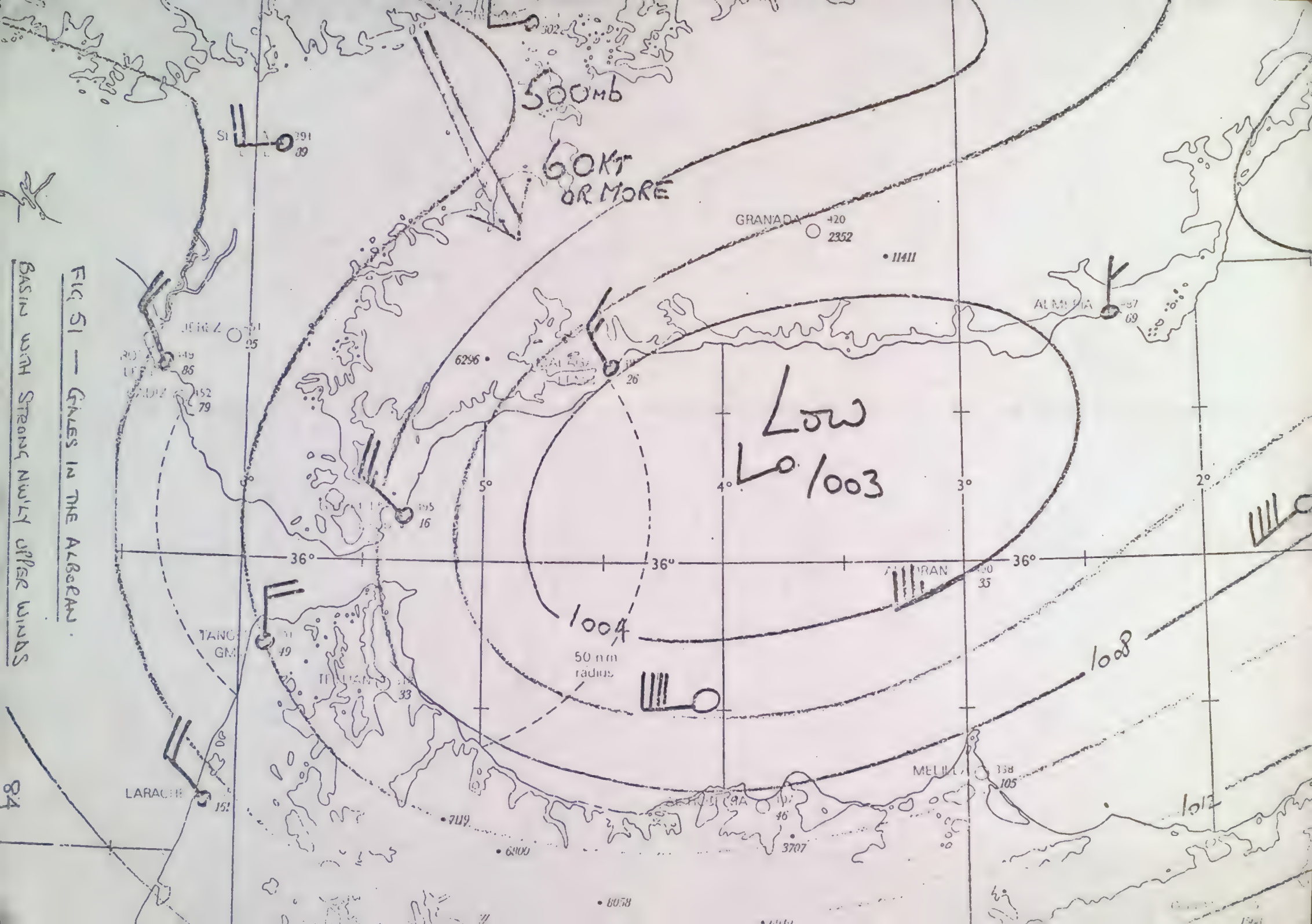


FIG 51 — GALES IN THE ALBORAN BASIN WITH STRONG NWLY UPPER WINDS

TABLE IX

CLIMATOLOGICAL DATA - NORTH FRONT, GIBRALTAR 1947 - 1976 (30 years)

Average number of days with:-	J	F	M	A	M	J	J	A	S	O	N	D	YEAR	
Snow or Sleet	0.03	0.03	-	-	-	-	-	-	-	-	-	-	0.06	
Snow lying	-	-	-	-	-	-	-	-	-	-	-	-	Nil	
Hail	0.3	0.5	0.7	0.2	0.2	-	-	-	-	0.03	0.03	0.5	2.46	
Thunder	1.4	1.6	1.9	1.9	1.5	1.3	0.5	0.5	1.4	2.0	2.5	2.4	18.9	
Fog	0.3	0.5	0.3	0.5	0.9	1.5	3.9	4.3	2.3	1.3	0.6	0.5	16.9	
Ground Frost	0.3	0.3	-	-	-	-	-	-	-	-	-	0.1	0.7	
Average number of days with Gales	0.5	0.9	0.7	0.2	0.0	0.03	-	0.03	-	0.03	0.4	0.6	3.40	
Highest number of Gales	4	3	6	2	0	1	-	1	-	1	2	2	8	(1947)
Average mean wind speed (kn) 1956	12.4	13.4	13.2	11.1	10.5	10.3	9.9	9.8	9.5	10.7	10.9	12.2	11.2	
Highest mean wind speed ") -	18.3	16.4	17.8	14.7	12.6	12.2	12.4	12.6	13.0	14.1	15.0	15.4	18.3	(Jan)
Lowest mean wind speed ") 1976	9.4	9.4	9.8	7.1	8.0	6.8	6.8	7.3	6.6	7.1	6.7	9.9	6.6	(Sept)
Average daily mean air temperature (°C)	13.1	13.5	14.8	16.4	18.7	21.1	23.6	24.3	22.3	19.4	16.0	13.8	18.1	
Highest daily mean air temperature "	14.3	15.4	16.6	17.9	21.5	22.8	25.3	26.6	24.2	21.6	17.5	15.5	26.6	(Aug)
Lowest daily mean air tempeature "	11.4	10.3	13.2	14.4	16.4	18.1	21.2	22.9	20.3	18.1	13.9	12.3	10.3	(Feb)
Average daily maximum temperature "	15.5	16.4	17.9	19.7	22.3	25.0	27.8	28.3	26.0	22.5	18.8	16.3	21.4	
Average daily minimum temperature "	10.4	10.8	11.9	13.0	15.2	17.5	19.8	20.5	19.0	16.6	13.4	11.1	14.9	
Highest recorded daily maximum temp. "	23.5	24.0	27.0	29.0	30.5	33.5(3)	38.0	38.8	33.6	33.5	29.3	24.0	38.8	(Aug) 9th/1976
Lowest recorded daily minimum temp. "	2.9	0.5	3.5	6.5	8.5	12.0	14.0	14.0	12.5	8.6	6.0	1.6	0.5	(Feb) 1st/2nd/1954
Average rainfall (mm)	139.7	104.6	98.8	60.0	36.0	9.6	0.3	1.4	20.6	58.5	123.5	144.4	797.4	
Highest rainfall "	507.3	351.4	207.8	184.9	118.3	53.1	4.4	17.1	142.0	198.9	478.9	417.7	1536.3	(1969)
Lowest rainfall "	24.7	2.8	14.3	Tr	0.4	-	-	-	-	Tr	1.6	0.7	404.6	(1974)
Highest recorded daily rainfall	293.9	100.2	70.8	45.5	60.1	22.1(1)	4.4(2)	9.7	97.3	78.3	128.9	117.0	293.9	(Jan) 30th/1959
Highest number of days with rainfall) 0.1mm or more	25	25	17	18	15	7	2	2	9	19	19	27	114	
) 1.0mm or more	21	19	15	15	10	5	1	2	7	14	18	23	95	
Lowest number of days with rainfall) 0.1mm or more	2	1	2	-	1	-	-	-	-	-	1	1	54	
) 1.0mm or more	2	1	2	-	-	-	-	-	-	-	1	-	45	
Average Sunshine (hrs)	155.5	153.0	195.6	246.5	299.3	320.6	344.5	325.9	259.3	208.1	151.7	144.4	2804.4	
Highest Sunshine "	208.1	219.8	249.4	294.2	349.4	353.8	380.0	355.4	311.8	257.0	223.7	221.8	3080.6	(1950)
Lowest Sunshine "	57.7	68.1	137.4	192.3	243.7	264.2	302.7	289.9	184.7	121.9	78.4	57.5	2207.4	(1971)
Average mean sea temperature in Bay (°C)	14.2	14.2	14.4	15.1	16.4	17.4	18.9	19.3	18.8	17.4	16.0	14.6	Based on 1962 - 1976 data	
Highest recorded sea temperature in Bay	16.1	16.1	16.1	17.2	21.1	21.1	24.4	23.9	23.3	22.2	19.4	16.7		
Lowest recorded sea temperature in Bay	12.2	12.2	12.8	13.3	13.9	15.0	16.1	15.6	15.6	14.4	12.2	11.1		

Meteorological Office Gibraltar
20th May 1977

NOTES:- (1) 35.1mm - 1ST JUNE 1977
(2) 8.0mm - 1ST JULY 1977
(3) 33.3°C - 12TH MAY 1977

TABLE Xa

ADDITIONAL CLIMATOLOGICAL DATA MONTH JANUARY

			Date/Period/Source	
A - TEMPERATURE				
1	Highest monthly mean	14.3°C	1969	1930-77
2	Lowest " "	10.2°C	1945	"
3	Highest MAX	23.9°C	MO 391b(1) p142	1874-1977
4	Lowest MIN	0.6°C	" "	"
5	Highest MIN	16.5°C	8th 1948	1930-77
6	Lowest MAX	7.0°C	17th 1957	"
7	Highest Wet Bulb (day)	17.2°C		1958-71
8	Lowest " " (night)	0.4°C		"
9	Average temp. at 0300Z	11.9°C		1964-73
10	" " " 0900Z	11.9°C		"
11	" " " 1500Z	15.1°C		"
12	" " " 2100Z	12.9°C		"
13	Average no. of days with MAX 30°C or more	NIL		1947-70
14	" " " " " " 25°C or more	NIL		"
15	" " " " " MIN 5°C or below	0.9		"
16	Average Grass Min.	1.4°C		1947-77
17	Lowest " "	MS 3.9°C	1954/1958	"
18	Highest " "	5.3°C	1964	"
B - RAINFALL				
1	Highest monthly total	549.2mm	1856	1852-1977
2	Lowest " "	0.8mm	1902	"
3	Highest daily "	293.9mm	30th 1959	1930-77
4	Average no. of days with 1.00mm or more	8.9		1946-70
5	" " " " " 10.00mm or more	3.9		"
C - RELATIVE HUMIDITY				
1	Average RH at 0300Z	82%		1964-73
2	" " " 0900Z	81%		"
3	" " " 1500Z	70%		"
4	" " " 2100Z	80%		"
D - SURFACE PRESSURE				
1	Highest recorded	1036.6mbs	MO 391 Vol I p58	
2	Lowest "	990.0 mbs	" " "	
E - CLOUD COVER				
1	Mean amount at 0300Z	3.8/8		1964-73
2	" " " 0900Z	4.9/8		"
3	" " " 1500Z	4.9/8		"
4	" " " 2100Z	3.8/8		"
5	Av. No. of days with clear sky	7	MO 391 Vol II p340	
6	" " " " " cloudy sky	8	" " "	

TABLE Xb

ADDITIONAL CLIMATOLOGICAL DATA MONTH FEBRUARY

			Date/Period/Source	
A - TEMPERATURE				
1	Highest monthly mean	15.4°C	1948	1930-77
2	Lowest " "	10.3°C	1956	"
3	Highest MAX	27.2°C	MO 391 6b(1) p142	1874-1977
4	Lowest MIN	0.5°C	1/2/54	1930-77
5	Highest MIN	16.0°C	14th 1958	"
6	Lowest MAX	8.5°C	1944/1954/1956	"
7	Highest Wet Bulb (day)	17.0°C		1958-71
8	Lowest " " (night)	1.5°C		"
9	Average temp. at 0300Z	12.3°C		1964-73
10	" " " 0900Z	12.4°C		"
11	" " " 1500Z	15.2°C		"
12	" " " 2100Z	13.2°C		"
13	Average no. of days with MAX 30°C or more	NIL		1947-70
14	" " " " " " 25°C or more	NIL		"
15	" " " " " MIN 5°C or below	1.0		"
16	Average Grass Min.	2.0°C		1947-77
17	Lowest " "	MS 6.1°C	1954	"
18	Highest " "	6.0°C	1967	"
B - RAINFALL				
1	Highest monthly total	381.2mm	1921	1852-1977
2	Lowest " "	NIL mm	1877	"
3	Highest daily "	100.2mm	5th 1972	1930-77
4	Average no. of days with 1.00mm or more	8.7		1946-70
5	" " " " " 10.00mm or more	3.6		1946-70
C - RELATIVE HUMIDITY				
1	Average RH at 0300Z	80%		1964-73
2	" " " 0900Z	78%		"
3	" " " 1500Z	68%		"
4	" " " 2100Z	78%		"
D - SURFACE PRESSURE				
1	Highest recorded	1036.3mbs	MO 391 Vol I p58	
2	Lowest "	994.5mbs	" " "	
E - CLOUD COVER				
1	Mean amount at 0300Z	4.1/8		1964-73
2	" " " 0900Z	5.0/8		"
3	" " " 1500Z	4.9/8		"
4	" " " 2100Z	4.1/8		"
5	Av. No. of days with clear sky	5	MO 391 Vol II p340	
6	" " " " " cloudy sky	5	" " "	

TABLE 12

ADDITIONAL CLIMATOLOGICAL DATA — MONTH MARCH

			Date/Period/Source	
A - TEMPERATURE				
1	Highest monthly mean	16.6°C	1952	1930-77
2	Lowest " "	12.6°C	1937	"
3	Highest MAX 1960	27.0°C	MO617c(III) p38	1874-1977
4	Lowest MIN	2.8°C	MO446b(1) p142	"
5	Highest MIN	17.0°C	20th 1950	1930-77
6	Lowest MAX	10.5°C	1st 1941	"
7	Highest Wet Bulb (day)	18.3°C		1958-71
8	Lowest " " (night)	3.4°C		"
9	Average temp. at 0300Z	12.8°C		1964-73
10	" " " 0900Z	13.5°C		"
11	" " " 1500Z	16.5°C		"
12	" " " 2100Z	13.9°C		"
13	Average no. of days with MAX 30°C or more	NIL		1947-70
14	" " " " " 25°C or more	0.3		"
15	" " " " " MIN 5°C or below	0.2		"
16	Average Grass Min.	3.7°C		"
17	Lowest " "	MS 1.7°C	1955	"
18	Highest " "	6.7°C	1957	"
B - RAINFALL				
1	Highest monthly total	451.1mm	1915	1852-1977
2	Lowest " "	NIL mm	1959	"
3	Highest daily "	70.8mm	25th 1969	1930-77
4	Average no. of days with 1.00mm or more	9.2		1946-70
5	" " " " " 10.00mm or more	3.5		"
C - RELATIVE HUMIDITY				
1	Average RH at 0300Z	82%		1964-73
2	" " " 0900Z	77%		"
3	" " " 1500Z	64%		"
4	" " " 2100Z	77%		"
D - SURFACE PRESSURE				
1	Highest recorded	1033.1mbs	MO 391 Vol I p58	
2	Lowest "	993.3mbs	" " "	
E - CLOUD COVER				
1	Mean amount at 0300Z	3.8/8		1964-73
2	" " " 0900Z	4.7/8		"
3	" " " 1500Z	4.6/8		"
4	" " " 2100Z	3.6/8		"
5	Av. No. of days with clear sky	4	MO 391 Vol II p 340	
6	" " " " " cloudy sky	9	" " "	

ADDITIONAL CLIMATOLOGICAL DATA MONTH APRIL

			Date/Period/Source	
A - TEMPERATURE				
1	Highest monthly mean	16.9°C	1961	1930-77
2	Lowest " "	11.4°C	1974	"
3	Highest MAX	30.6°C	MO 446b(1) p142	1874-1977
4	Lowest MIN	6.5°C	" "	"
5	Highest MIN	21.6°C	22nd 1945	1930-77
6	Lowest MAX	10.5°C	1958	"
7	Highest Wet Bulb (day)	18.7°C		1958-71
8	Lowest " " (night)	5.0°C		"
9	Average temp. at 0300Z	13.7°C		1964-73
10	" " " 0900Z	18.1°C		"
11	" " " 1500Z	16.4°C		"
12	" " " 2100Z	17.4°C		"
13	Average no. of days with MAX 30°C or more	NIL*		1947-70
14	" " " " " " 25°C or more	0.7		"
15	" " " " " MIN 5°C or below	NIL		"
16	Average Grass Min.	5.8°C		1947-77
17	Lowest " "	2.7°C	1973	"
18	Highest " "	7.8°C	1960/61/63	"
B - RAINFALL				
1	Highest monthly total	196.1mm	1911	1852-1977
2	Lowest " "	TR mm	Various	1852-1977
3	Highest daily "	74.5mm	3rd 1932	1930-77
4	Average no. of days with 1.00mm or more	6.0		1947-70
5	" " " " " 10.00mm or more	1.6		"
C - RELATIVE HUMIDITY				
1	Average RH at 0300Z	81%		1964-73
2	" " " 0900Z	74.0%		"
3	" " " 1500Z	61%		"
4	" " " 2100Z	77%		"
D - SURFACE PRESSURE				
1	Highest recorded	1028.5mbs	MO 391 Vol I p68	
2	Lowest "	994.7mbs	" " "	
E - CLOUD COVER				
1	Mean amount at 0300Z	3.2/8		1964-73
2	" " " 0900Z	4.2/8		"
3	" " " 1500Z	4.0/8		"
4	" " " 2100Z	2.8/8		"
5	Av. No. of days with clear sky	6	MO 391 Vol II p340	
6	" " " " " cloudy sky	5	" " "	

* But see A3

TABLE Xc

ADDITIONAL CLIMATOLOGICAL DATA — MONTH: MAY

			Date/Period/Source	
A – TEMPERATURE				
1	Highest monthly mean	21.5°C	1955	1930-77
2	Lowest " "	15.1°C	1936	"
3	Highest MAX	33.3°C	12th 1977	"
4	Lowest MIN	7.2°C	MO 446b(1)	1874-1977
5	Highest MIN	20.5°C	1953/55/60	1930-77
6	Lowest MAX	13.9°C	7th 1936	"
7	Highest Wet Bulb (day)	21.2°C		1958-71
8	Lowest " " (night)	7.6°C		"
9	Average temp. at 0300Z	16.0°C		1964-73
10	" " " 0900Z	18.1°C		"
11	" " " 1500Z	20.6°C		"
12	" " " 2100Z	17.4°C		"
13	Average no. of days with MAX 30°C or more	0.2		1947-70
14	" " " " " " 25°C or more	5.9		"
15	" " " " " MIN 5°C or below	NIL		"
16	Average Grass Min.	7.7°C		1947-77
17	Lowest " "	3.9°C	1954	1947-77
18	Highest " "	11.1°C	1955/65	"
B – RAINFALL				
1	Highest monthly total	164.6mm	1853	1852-1977
2	Lowest " "	NIL mm	1860/69	"
3	Highest daily "	60.1 mm	25th 1963	1930-77
4	Average no. of days with 1.00mm or more	3.9		1947-70
5	" " " " " 10.00mm or more	1.0		"
C – RELATIVE HUMIDITY				
1	Average RH at 0300Z	82%		1964-73
2	" " " 0900Z	73%		"
3	" " " 1500Z	62%		"
4	" " " 2100Z	78%		"
D – SURFACE PRESSURE				
1	Highest recorded	1027.7mbs	MO 391 Vol I p 58	
2	Lowest "	1002.9mbs	" " "	
E – CLOUD COVER				
1	Mean amount at 0300Z	2.4/8		1964-73
2	" " " 0900Z	3.9/8		"
3	" " " 1500Z	3.3/8		"
4	" " " 2100Z	2.7/8		"
5	Av. No. of days with clear sky	7	MO 391 Vol II p 340	
6	" " " " " cloudy sky	3	" " "	

TABLE X.f

ADDITIONAL CLIMATOLOGICAL DATA MONTH JUNE

		Date/Period/Source	
A - TEMPERATURE			
1 Highest monthly mean	22.9°C	1952	1930-77
2 Lowest " "	16.0°C	1958	"
3 Highest MAX	36.1°C	Met O 446b(1) p142	1874-1977
4 Lowest MIN	9.5°C	"	" "
5 Highest MIN	24.5°C	22nd 1965	1930-77
6 Lowest MAX	17.0°C	3rd & 6th 1936	"
7 Highest Wet Bulb (day)	23.9°C		1958-71
8 Lowest " " (night)	10.5°C		"
9 Average temp. at 0300Z	16.0°C		1964-73
10 " " " 0900Z	20.4°C		"
11 " " " 1500Z	23.3°C		"
12 " " " 2100Z	19.6°C		"
13 Average no. of days with MAX 30°C or more	1.0		1946-70
14 " " " " " " 25°C or more	15.4		"
15 " " " " " MIN 5°C or below	NIL		"
16 Average Grass Min.	11.3°C		1947-77
17 Lowest " "	6.1°C	1959	"
18 Highest " "	15.6°C	1955	"
B - RAINFALL			
1 Highest monthly total	148.9mm	1930	1852-1977
2 Lowest " "	NIL mm	Various	"
3 Highest daily "	35.1 mm	1st 1977	1930-77
4 Average no. of days with 1.00mm or more	1.6		1946-70
5 " " " " " 10.00mm or more	NIL *		"
C - RELATIVE HUMIDITY			
1 Average RH at 0300Z	81%		1964-73
2 " " " 0900Z	72%		"
3 " " " 1500Z	61%		"
4 " " " 2100Z	77%		"
D - SURFACE PRESSURE			
1 Highest recorded	1025.7mbs	MO 391 Vol I p58	
2 Lowest "	1004.1mbs	" "	"
E - CLOUD COVER			
1 Mean amount at 0300Z	2.3/8		1964-73
2 " " " 0900Z	3.4/8		"
3 " " " 1500Z	2.4/8		"
4 " " " 2100Z	2.1/8		"
5 Av. No. of days with clear sky	12	MO 391 Vol II p340	
6 " " " " " cloudy sky	1	" "	"

* But see B3

TABLE 2g

ADDITIONAL CLIMATOLOGICAL DATA MONTH JULY

			Date/Period/Source
A - TEMPERATURE			
1	Highest monthly mean	25.3°C	1950 1930-77
2	Lowest " "	21.2°C	1961 "
3	Highest MAX	38.3°C	MO 1166b(1) p112 1874-1977
4	Lowest MIN	12.8°C	" " "
5	Highest MIN	24.5°C	1947/62/63 1930-77
6	Lowest MAX	21.1°C	2nd 1938, 13th 1940 "
7	Highest Wet Bulb (day)	25.8°C	1958-71
8	Lowest " " (night)	11.7°C	"
9	Average temp. at 0300Z	20.5°C	1964-73
10	" " " 0900Z	22.7°C	"
11	" " " 1500Z	26.1°C	"
12	" " " 2100Z	22.2°C	"
13	Average no. of days with MAX 30°C or more	6.2	1946-70
14	" " " " " " 25°C or more	28.2	"
15	" " " " " MIN 5°C or below	NIL	"
16	Average Grass Min.	14.3°C	1947-77
17	Lowest " "	8.3°C	1954 "
18	Highest " "	17.8°C	1955 "
B - RAINFALL			
1	Highest monthly total	15.8mm	1881 1852-1977
2	Lowest " "	NIL mm	Various "
3	Highest daily "	8.0mm	1st 1977 1930-77
4	Average no. of days with 1.00mm or more	0.1	1946-70
5	" " " " " 10.00mm or more	NIL	"
C - RELATIVE HUMIDITY			
1	Average RH at 0300Z	82%	1964-73
2	" " " 0900Z	73%	"
3	" " " 1500Z	61%	"
4	" " " 2100Z	76%	"
D - SURFACE PRESSURE			
1	Highest recorded	1025.5 mbs	MO 391 Vol I p58
2	Lowest "	1006.3 mbs	" " "
E - CLOUD COVER			
1	Mean amount at 0300Z	1.9/8	1964-73
2	" " " 0900Z	2.7/8	"
3	" " " 1500Z	1.2/8	"
4	" " " 2100Z	1.4/8	"
5	Av. No. of days with clear sky	17	MO 391 Vol II p340
6	" " " " " cloudy sky	0.4	" " "

TABLE Xh

ADDITIONAL CLIMATOLOGICAL DATA — MONTH: AUGUST

			Date/Period/Source	
A – TEMPERATURE				
1	Highest monthly mean	26·6°C	1949	1930-77
2	Lowest " "	21·6°C	1965	"
3	Highest MAX	38·8°C	9th 1976	1874-1977
4	Lowest MIN	23rd 1954 13·9°C	MO 488b(1) p142	1874-1977
5	Highest MIN	25·0°C	1949/57/62	1930-77
6	Lowest MAX	21·0°C	1956	"
7	Highest Wet Bulb (day)	25·0°C		1953-71
8	Lowest " " (night)	13·3°C		"
9	Average temp. at 0300Z	21·3°C		1964-73
10	" " " 0900Z	23·1°C		"
11	" " " 1500Z	26·8°C		"
12	" " " 2100Z	22·5°C		"
13	Average no. of days with MAX 30°C or more	8·2		1946-70
14	" " " " " " 25°C or more	29·4		"
15	" " " " " MIN 5°C or below	NIL		"
16	Average Grass Min.	15·2°C		1947-77
17	Lowest " "	11·1°C	1954	"
18	Highest " "	17·2°C	1957	"
B – RAINFALL				
1	Highest monthly total	43·2 mm	1854	1852-1977
2	Lowest " "	NIL mm	Various	"
3	Highest daily "	9·8 mm	6th 1956	1930-77
4	Average no. of days with 1.00mm or more	0·3		1946-70
5	" " " " " 10.00mm or more	NIL		"
C – RELATIVE HUMIDITY				
1	Average RH at 0300Z	81%		1964-73
2	" " " 0900Z	74%		"
3	" " " 1500Z	60%		"
4	" " " 2100Z	77%		"
D – SURFACE PRESSURE				
1	Highest recorded	1023·8mbs	MO 391 Vol I p58	
2	Lowest "	1007·8mbs	" " "	
E – CLOUD COVER				
1	Mean amount at 0300Z	2·3/8		1964-73
2	" " " 0900Z	3·0/8		"
3	" " " 1500Z	1·6/8		"
4	" " " 2100Z	1·7/8		"
5	Av. No. of days with clear sky	15	MO 391 Vol II p340	
6	" " " " " cloudy sky	1	" " "	

TABLE XI

ADDITIONAL CLIMATOLOGICAL DATA MONTH SEPTEMBER

			Date/Period/Source	
A - TEMPERATURE				
1	Highest monthly mean	24.2°C	1949	1930-77
2	Lowest " "	20.3°C	1964	"
3	Highest MAX	35.0°C	MO 446b(1) p142	1874-1977
4	Lowest MIN	10.0°C	" "	"
5	Highest MIN	25.0°C	1st 1955	1930-77
6	Lowest MAX	19.9°C	29th 1967	"
7	Highest Wet Bulb (day)	25.0°C		1958-71
8	Lowest " " (night)	11.7°C		"
9	Average temp. at 0300Z	19.7°C		1964-73
10	" " " 0900Z	20.8°C		"
11	" " " 1500Z	24.3°C		"
12	" " " 2100Z	20.7°C		"
13	Average no. of days with MAX 30°C or more	1.8		1946-70
14	" " " " " " 25°C or more	21.2		"
15	" " " " " MIN 5°C or below	NIL		"
16	Average Grass Min.	12.9°C		1947-77
17	Lowest " "	9.1°C	1975	"
18	Highest " "	17.8°C	1955	"
B - RAINFALL				
1	Highest monthly total	215.9mm	1905	1852-1977
2	Lowest " "	NIL mm	Various	"
3	Highest daily "	97.3 mm	9th 1949	1930-77
4	Average no. of days with 1.00mm or more	2.0		1946-70
5	" " " " " 10.00mm or more	0.6		"
C - RELATIVE HUMIDITY				
1	Average RH at 0300Z	83%		1964-73
2	" " " 0900Z	76%		"
3	" " " 1500Z	63%		"
4	" " " 2100Z	80%		"
D - SURFACE PRESSURE				
1	Highest recorded	1028.2mbs	MO 391 Vol I p58	
2	Lowest "	1006.4mbs	" " "	
E - CLOUD COVER				
1	Mean amount at 0300Z	2.9/8		1964-73
2	" " " 0900Z	2.7/8		"
3	" " " 1500Z	3.1/8		"
4	" " " 2100Z	2.5/8		"
5	Av. No. of days with clear sky	9	MO 391 Vol II p340	
6	" " " " " cloudy sky	2	" " "	

TABLE Xj

ADDITIONAL CLIMATOLOGICAL DATA MONTH OCTOBER

			Date/Period/Source	
A - TEMPERATURE				
1	Highest monthly mean	21.6°C	1971	1930-77
2	Lowest " "	17.5°C	1937	"
3	Highest MAX 12th 1942	35.5°C	MO 446b(1) p142	1874-1977
4	Lowest MIN	6.6°C	"	" "
5	Highest MIN	23.9°C	12th 1942	1930-77
6	Lowest MAX	13.9°C	31st 1944	1947-77
7	Highest Wet Bulb (day)	22.0°C		1958-71
8	Lowest " " (night)	7.0°C		"
9	Average temp. at 0300Z	17.7°C		1964-73
10	" " " 0900Z	18.5°C		"
11	" " " 1500Z	21.3°C		"
12	" " " 2100Z	18.4°C		"
13	Average no. of days with MAX 30°C or more	0.2		1946-70
14	" " " " " " 25°C or more	4.1		"
15	" " " " " MIN 5°C or below	NIL		"
16	Average Grass Min.	8.9°C		1947-77
17	Lowest " "	5.1°C	1976	"
18	Highest " "	12.4°C	1971	"
B - RAINFALL				
1	Highest monthly total	314.2mm	1963	1852-1977
2	Lowest " "	TR mm	1949/64	"
3	Highest daily "	76.3mm	24th 1959	1930-77
4	Average no. of days with 1.00mm or more	4.8		1946-70
5	" " " " " 10.00mm or more	2.0		"
C - RELATIVE HUMIDITY				
1	Average RH at 0300Z	85%		1964-73
2	" " " 0900Z	81%		"
3	" " " 1500Z	70%		"
4	" " " 2100Z	83%		"
D - SURFACE PRESSURE				
1	Highest recorded	1030.3mbs	MO 391 Vol I p 58	
2	Lowest "	995.1mbs	" " "	
E - CLOUD COVER				
1	Mean amount at 0300Z	3.5/8		1964-73
2	" " " 0900Z	4.5/8		"
3	" " " 1500Z	4.0/8		"
4	" " " 2100Z	3.6/8		"
5	Av. No. of days with clear sky	7	MO 391 Vol II p 340	
6	" " " " " cloudy sky	5	" " "	

TABLE 2K

ADDITIONAL CLIMATOLOGICAL DATA MONTH NOVEMBER

			Date/Period/Source
A - TEMPERATURE			
1 Highest monthly mean		17.5°C	1950/54 1930-77
2 Lowest " "		13.3°C	1933 "
3 Highest MAX	15th 1975	29.3°C	MO 414b(1) p142 1874-1977
4 Lowest MIN		1.6°C	" " "
5 Highest MIN		18.9°C	20th 1947 1930-77
6 Lowest MAX		10.2°C	1969 "
7 Highest Wet Bulb (day)		19.1°C	1958-71
8 Lowest " " (night)		3.0°C	"
9 Average temp. at 0300Z		14.4°C	1964-73
10 " " " 0900Z		14.8°C	"
11 " " " 1500Z		17.5°C	"
12 " " " 2100Z		15.3°C	"
13 Average no. of days with MAX 30°C or more		NIL	1946-70
14 " " " " " " 25°C or more		0.3	"
15 " " " " " MIN 5°C or below		NIL	"
16 Average Grass Min.		5.1°C	1947-77
17 Lowest " "		2.0°C	1971 "
18 Highest " "		9.4°C	1955 "
B - RAINFALL			
1 Highest monthly total		633.2mm	1858 1852-1977
2 Lowest " "		NIL mm	1866/83 "
3 Highest daily "		145.9mm	29th 1945 1930-77
4 Average no. of days with 1.00mm or more		8.2	1946-70
5 " " " " " 10.00mm or more		3.8	"
C - RELATIVE HUMIDITY			
1 Average RH at 0300Z		83%	1964-73
2 " " " 0900Z		81%	"
3 " " " 1500Z		70%	"
4 " " " 2100Z		80%	"
D - SURFACE PRESSURE			
1 Highest recorded		1031.1mbs	MO 391 Vol I p 58
2 Lowest "		986.4mbs	30th 1947
E - CLOUD COVER			
1 Mean amount at 0300Z		3.7/8	1964-73
2 " " " 0900Z		4.9/8	"
3 " " " 1500Z		4.6/8	"
4 " " " 2100Z		3.9/8	"
5 Av. No. of days with clear sky		4	MO 391 Vol II p 340
6 " " " " " cloudy sky		8	" " "

ADDITIONAL CLIMATOLOGICAL DATA — MONTH DECEMBER

			Date/Period/Source	
A - TEMPERATURE				
1	Highest monthly mean	15.5°C	1955/57	1930-77
2	Lowest " "	10.9°C	1933	"
3	Highest MAX	25.0°C	MO 446b(i) p142	1874-1977
4	Lowest MIN	MS 1.1°C	"	" "
5	Highest MIN	17.0°C	1955/61	1930-77
6	Lowest MAX	7.5°C	18th 1946	1947-77
7	Highest Wet Bulb (day)	17.2°C		1953-71
8	Lowest " " (night)	0.0°C		"
9	Average temp. at 0300Z	11.6°C		1964-73
10	" " " 0900Z	11.7°C		"
11	" " " 1500Z	15.1°C		"
12	" " " 2100Z	12.6°C		"
13	Average no. of days with MAX 30°C or more	NIL		1946-70
14	" " " " " " 25°C or more	0.5		"
15	" " " " " MIN 5°C or below	2.6		"
16	Average Grass Min.	2.6°C		1947-77
17	Lowest " "	MS 2.4°C	25th 1970	"
18	Highest " "	7.2°C	1961	"
B - RAINFALL				
1	Highest monthly total	598.7mm	1861	1852-1977
2	Lowest " "	0.8mm	1854	"
3	Highest daily "	117.0mm	26th 1962	1930-77
4	Average no. of days with 1.00mm or more	9.2		1946-70
5	" " " " " 10.00mm or more	3.9		"
C - RELATIVE HUMIDITY				
1	Average RH at 0300Z	80%		1964-73
2	" " " 0900Z	78%		"
3	" " " 1500Z	67%		"
4	" " " 2100Z	78%		"
D - SURFACE PRESSURE				
1	Highest recorded	1034.3mbs	MO 391 Vol I p58	
2	Lowest "	986.8mbs	15th 1975	
E - CLOUD COVER				
1	Mean amount at 0300Z	2.9/8		1964-73
2	" " " 0900Z	4.1/8		"
3	" " " 1500Z	3.9/8		"
4	" " " 2100Z	3.1/8		"
5	Av. No. of days with clear sky	6	MO 391 Vol II p340	
6	" " " " " cloudy sky	7	"	"

APPENDIX B - SOME EXAMPLES OF SYNOPTIC SITUATIONS.

FIG(S).

51 - Gales in the Alboran Basin with strong upper NW'ly flow

52-53 - SW'ly winds freshening to gale force ahead of an approaching cold front.

54 - Gale force westerlies.

55-59 - A CONTRASTE situation.

60-62 - A rapid change from moderate westerlies to strong easterlies in summer.

63-66 - Another example of a rapid change from westerlies to strong easterlies in summer.

67-69 - Large local variations of surface pressure and winds in the Alboran Basin.

70 - A CONTRASTE situation with cyclogenesis in the Alboran Basin.

71-77 - A thundery sequence in summer.

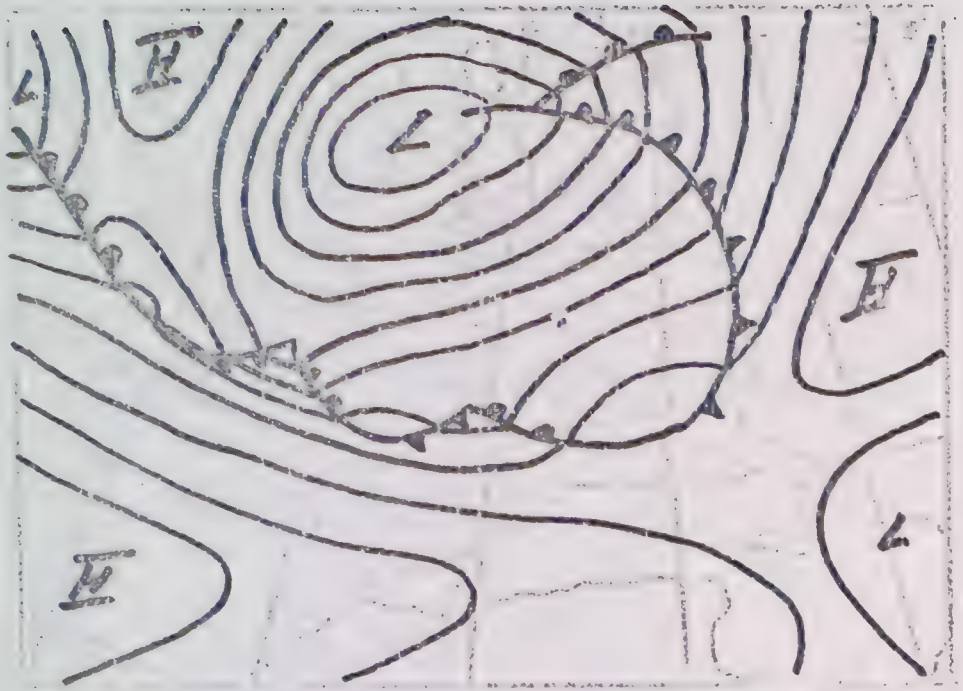


Fig 52 1ST JAN 1951 1200Z

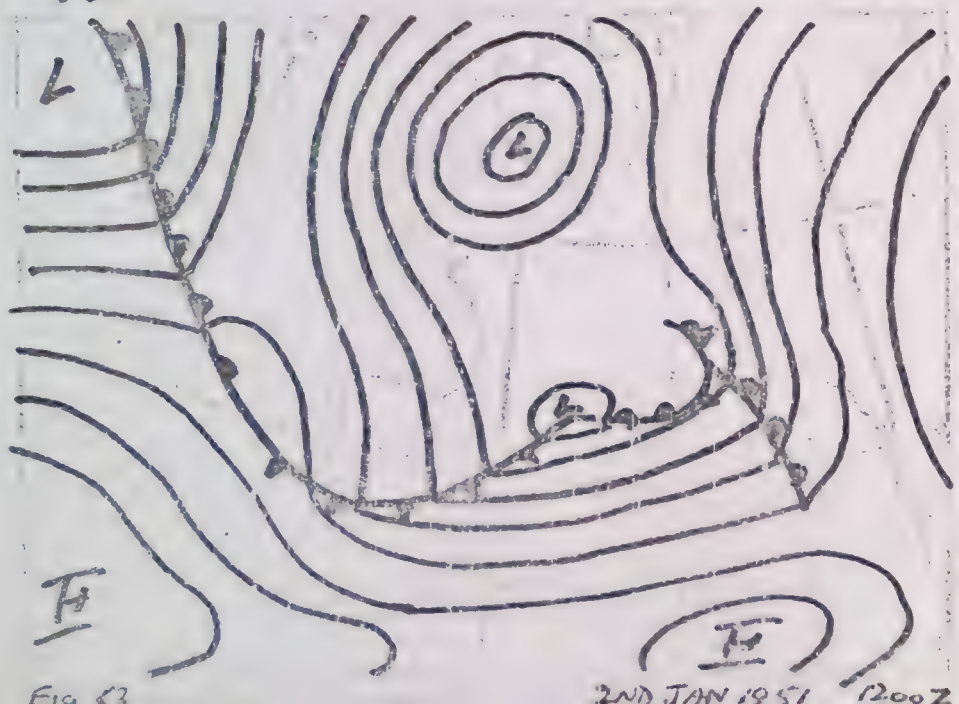
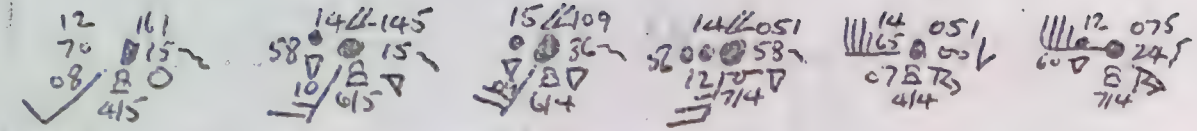


Fig 53 2ND JAN 1951 1200Z

56 187 81 117 49 8 715 1/1/51 12Z	55 171 70 005 51 8 714 1/1/51 18Z	55 163 80 10 51 5/5 2/1/51 00Z	QNT36 53 108 70 36 51 3 614 2/1/51 06Z	QNT44 51 048 04 43 52K 9 714 2/1/51 12Z
QNT57 56 020 814 2/1/51 14Z	QNT41 57 086 53 224 814 2/1/51 15Z	M034 81 8 414 2/1/51 16Z		

NOTES:-

Southwesterly winds freshening to gale force ahead of a cold front approaching from the north.



4/3/75 06 4/3/75 12 4/3/75 15 4/3/75 18 4/3/75 21 4/3/75 24

Gale Force Westerlies. (Fig 52)

A deepening low moved into the Portuguese coast near Porto and continued SE across Spain into the Alboran Basin. The warm front passed east of Gibraltar at 1700Z followed by the cold at 1930Z, the passage of which was accompanied by thunder. The surface wind at 1830Z was 210/34 kts with gusts to 55 kts.

It is rather unusual for depressions to track north of Gibraltar - the more common track is into the Gulf of Cadiz and then east through the Straits.

100

GIBRALTAR 06 4/3/75 24 4/3/75

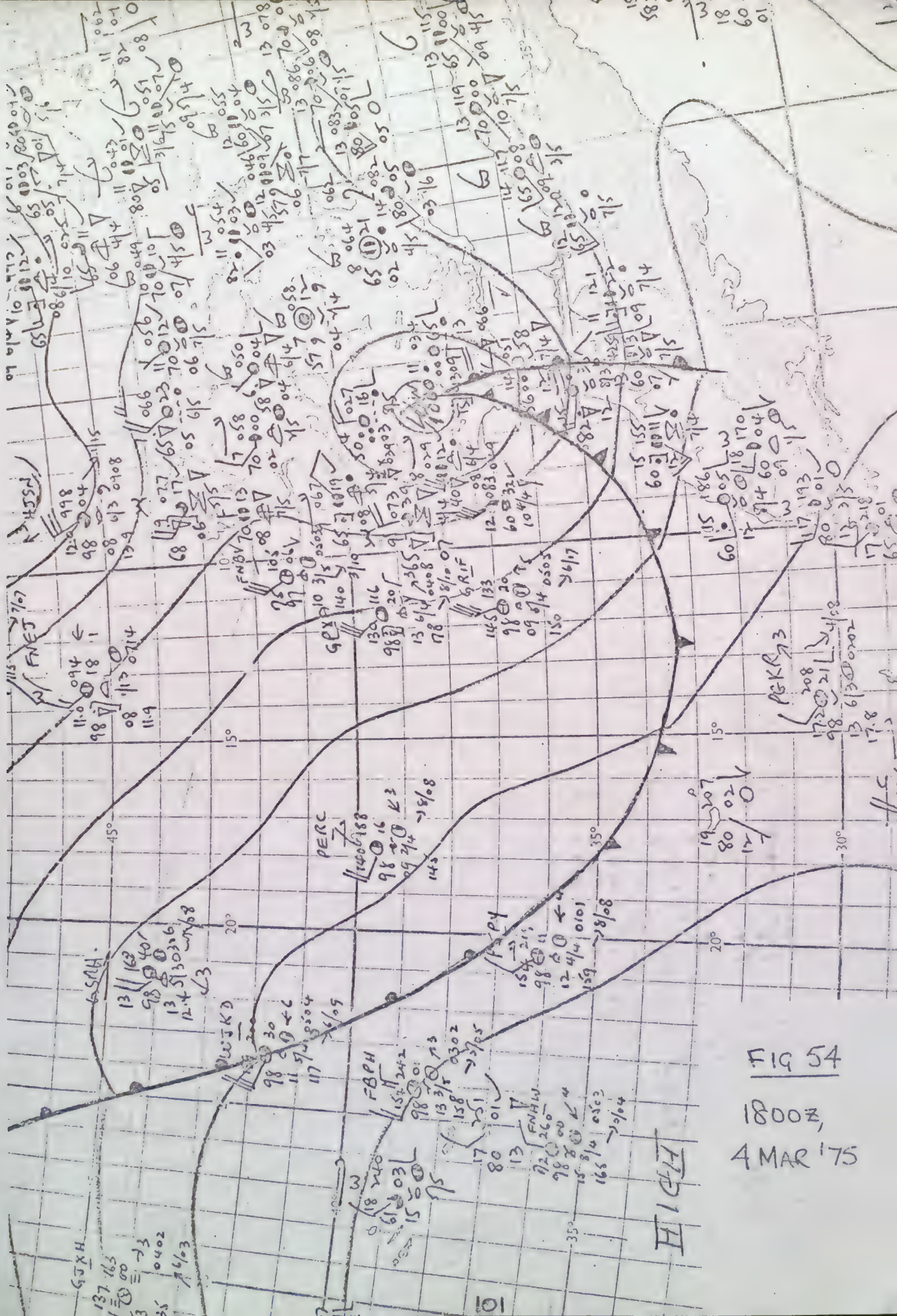
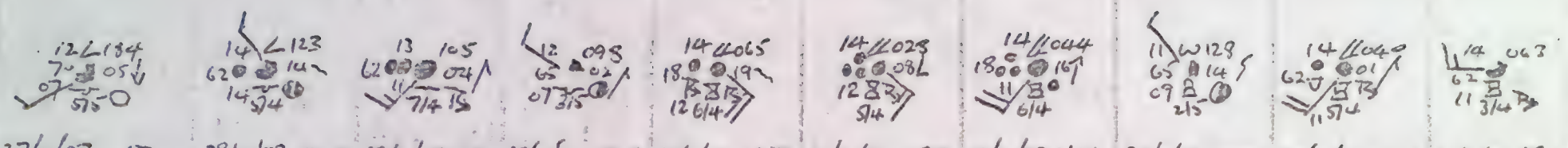


FIG 54

1800Z,
4 MAR '75



27/11/77 00 | 28/11/77 00 | 28/11/77 12 | 29/11/77 00 | 29/11/77 12 | 29/11/77 18 | 29/11/77 21 | 30/11/77 00 | 30/11/77 06 | 30/11/77 15

Contraste Situation. A low formed near OWS Charlie (53N 35½W) on 25 Nov 1977 and moved SE whilst deepening slowly. At 270000Z, it was centred at 42N11W with central pressure 1012mb, and an associated cold front extending from near Comnna to Rota and thence SW to the Canaries. By 280000z, the associated 300mb trough lay near the W coast of Portugal with evidence of a wave developing near Madeira. By 281200Z the upper trough was just west of Gibraltar and the associated surface cold front passed east of the station at 1500Z giving continuous moderate rain and thunder. A new upper trough formed between OWS Romeo and the Azores and moved east resulting in a SW'ly flow aloft over Gibraltar and maintaining showery conditions in the Straits area.As this trough approached the Gulf of Cadiz, the associated surface low resulted in the onset of E-SE winds at Gibraltar which reached 22 kts gusting 33 kts by late afternoon on 29th. Nov. , continuous moderate rain, and later occasional heavy rain with thunder.The surface wind veered to the SW as the surface front approached, and then to the NW on passage of the front with a temporary clearance at 300000Z. This clearance was however short-lived and the wind soon returned to the SW and heavy showers and thunderstorms prevailed until the upper trough passed east of the station by mid-afternoon on 30th. Nov.

The main points to note about this situation are:-

(1) The veer of the Gibraltar surface wind from SE to SW as the surface front approached.
(2) On passage of the surface front, the clearance at Gibraltar was only temporary.
(3) The final clearance did not occur until the 300 mb trough passed east of the station.
(4) As the 850-700mb flow ahead of the upper trough backed to 210 deg. or less, pressure began to fall in the Alboran Basin, causing the formation of a small lee low and the lessening of the easterly gradient across the Straits.

SEE FIGS 55-59

GIBRALTAR 0000Z ON 27 NOV 1977 TO 1500Z ON 30 NOV 1977

102

Fig 55 28 NOV 77 1200Z

Fig 56 29 NOV 77 00Z

Fig 57 29 NOV 77 1200Z

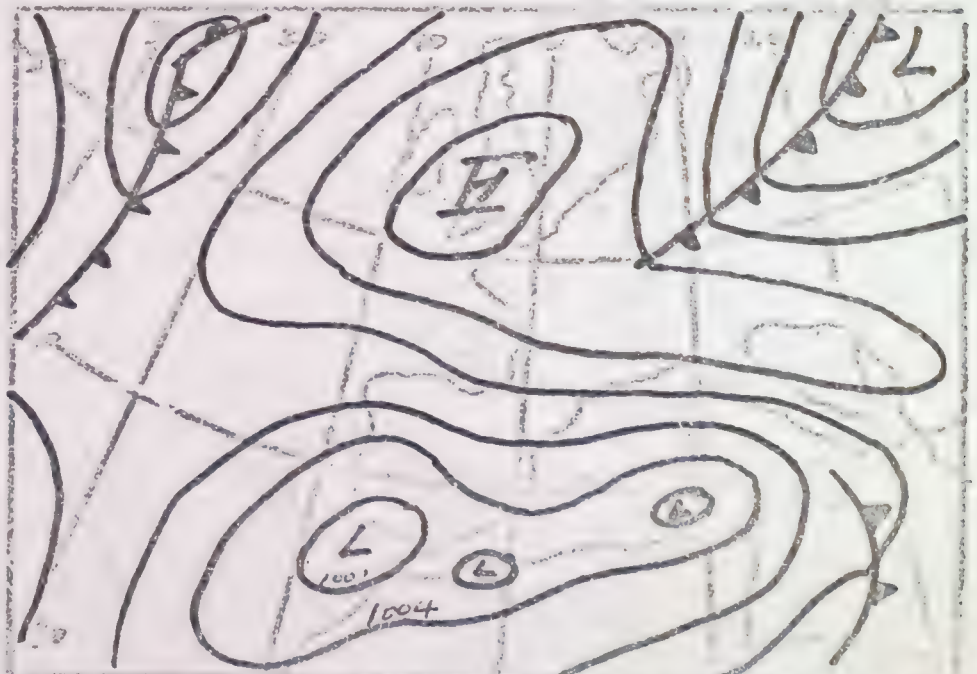


Fig 58 30 NOV 77 00Z

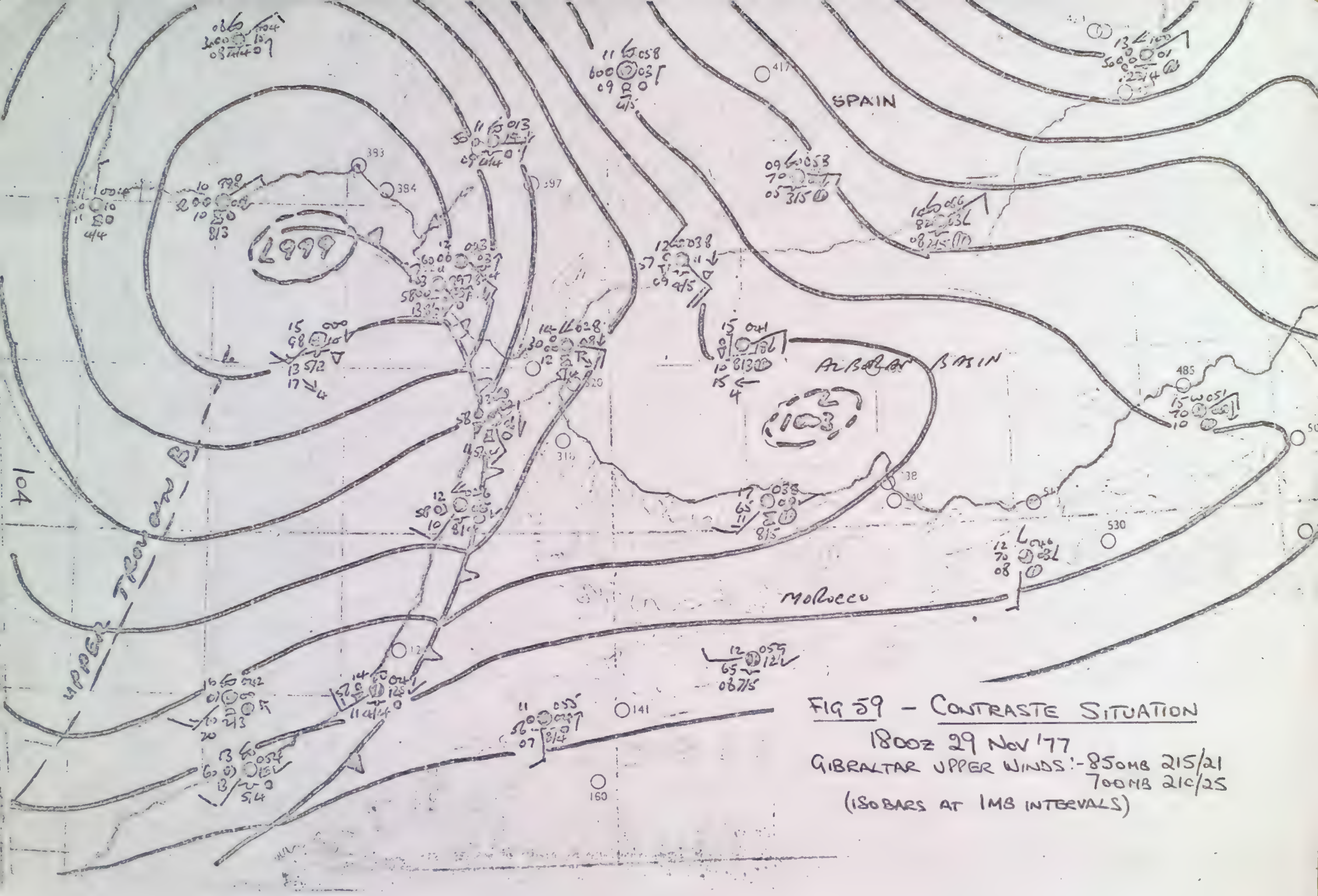


FIG 59 – CONTRASTE SITUATION

1800Z 29 NOV '77

GIBRALTAR UPPER WINDS:- 850MB 215/21
700MB 210/25

(ISOBARS AT 1MB INTERVALS)

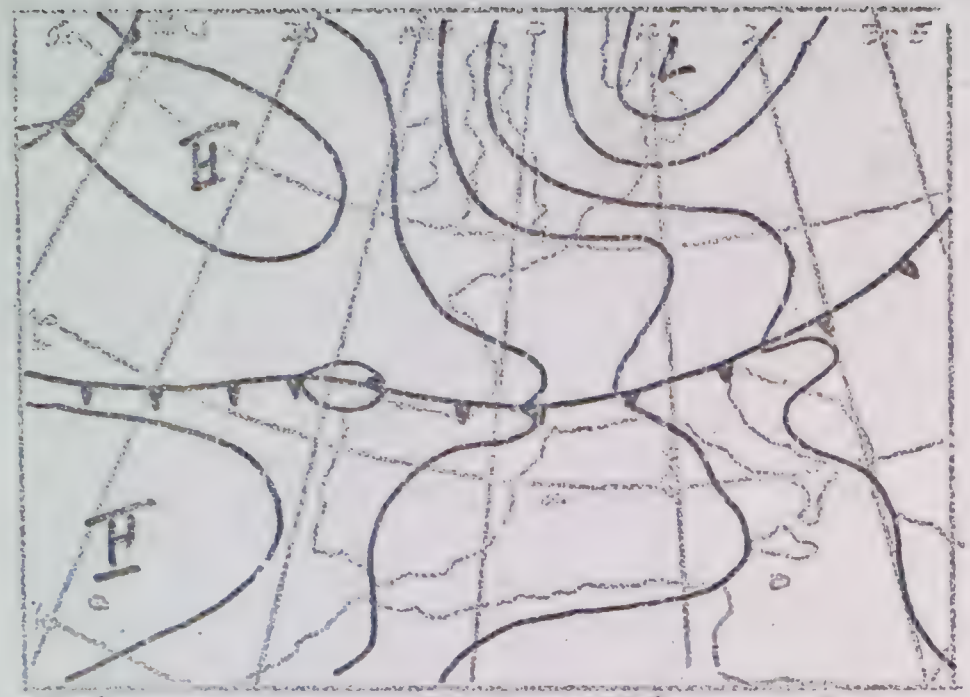


Fig 60 26 JUN 1978 00Z

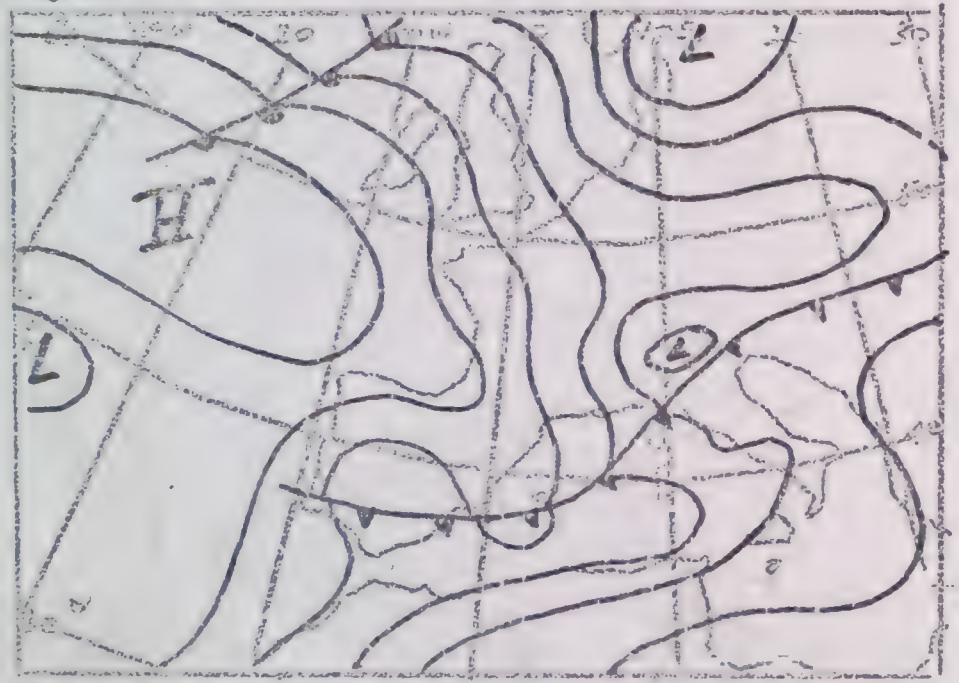


Fig 61 27 JUN 1978 00Z

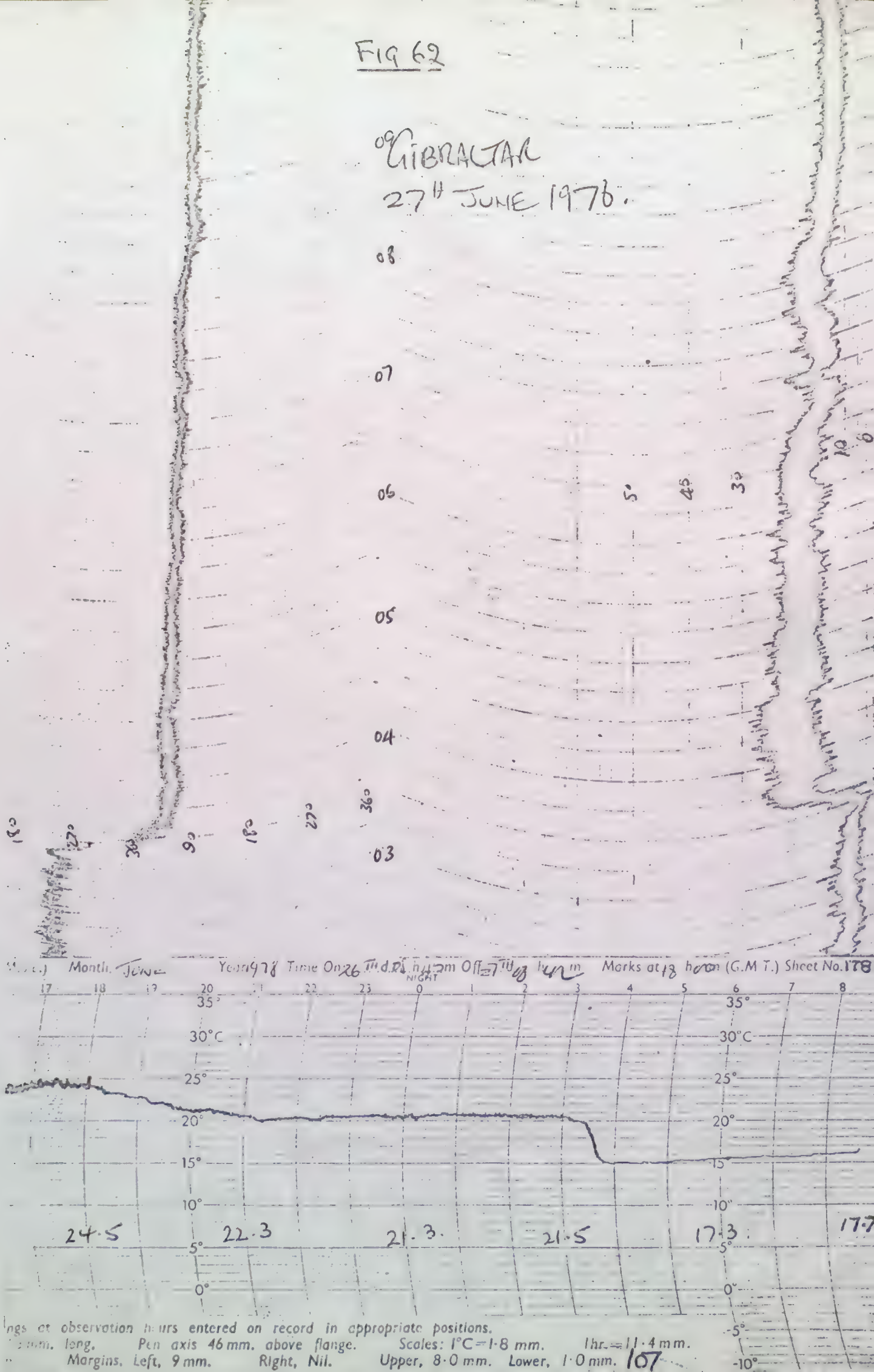
27/6/78 03Z	27/6/78 04Z	27/6/78 05Z	27/6/78 06Z	

NOTES:-

The weak cold front over N. Spain on 26th. moved south with no weather and very little cloud. On reaching The Alboran Basin at 0330Z on 27th. a rapid change from moderate westerlies to strong easterlies occurred at Gibraltar. The air temperature fell sharply by 5 deg.C and RH rose from 62 percent to 82 percent. Stratus started to appear at 1300ft. at 0448Z and cloud cover increased rapidly to 1/8 at 1200ft. and 5/8 at 1600 ft. by 0547Z.

This type of occurrence which was not forecast underlines the importance of tracing old cold fronts down the east coast of Spain in the summer months even if there is no associated cloud or weather.

FIG 62



GIBRALTAR
27th JUNE 1976.
08
07
06
05
04
03
Month. June
Year 1978
Time On 26 Th d.m. h 17 m Off 27 Th 08 h 42 m
Marks at 18 hours (G.M.T.) Sheet No. 178
NIGHT
35°
30°C
25°
20°
15°
10°
5°
0°
-5°
-10°
24.5
22.3
21.3
21.5
17.3
17.7
ngs at observation hours entered on record in appropriate positions.
mm. long. Pen axis 46 mm. above flange. Scales: 1°C = 1·8 mm. 1 hr. = 11·4 mm.
Margins, Left, 9 mm. Right, Nil. Upper, 8·0 mm. Lower, 1·0 mm.

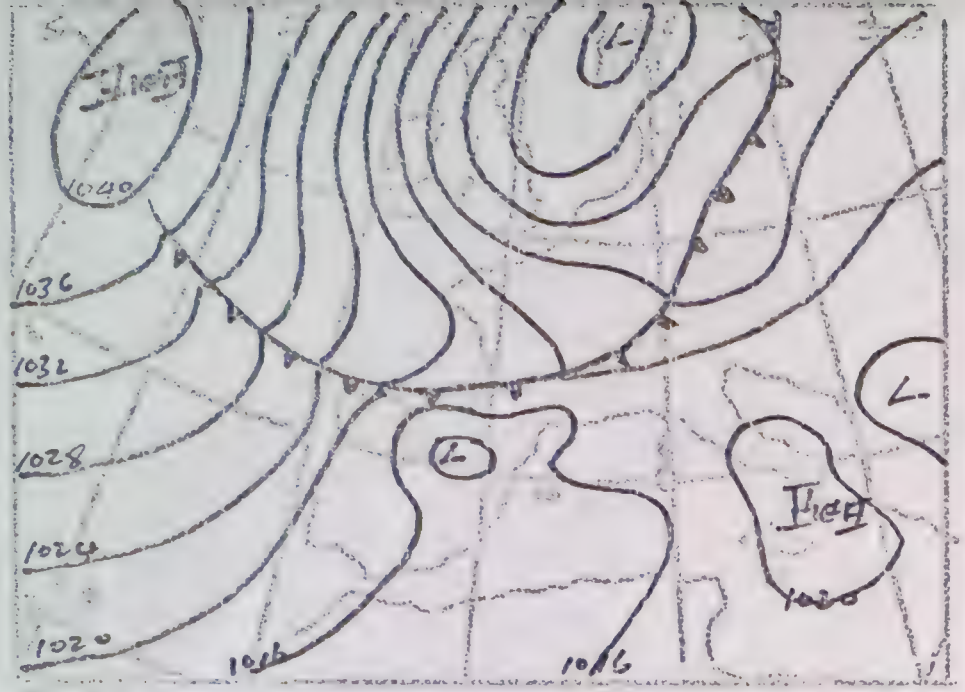


Fig 63

4 JULY 1978 1200Z

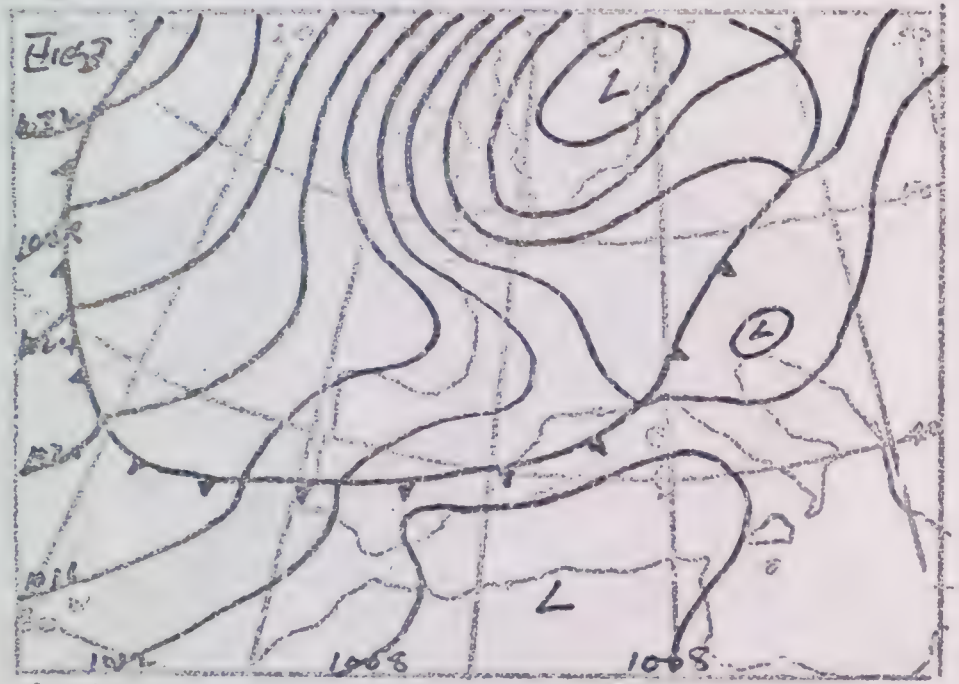


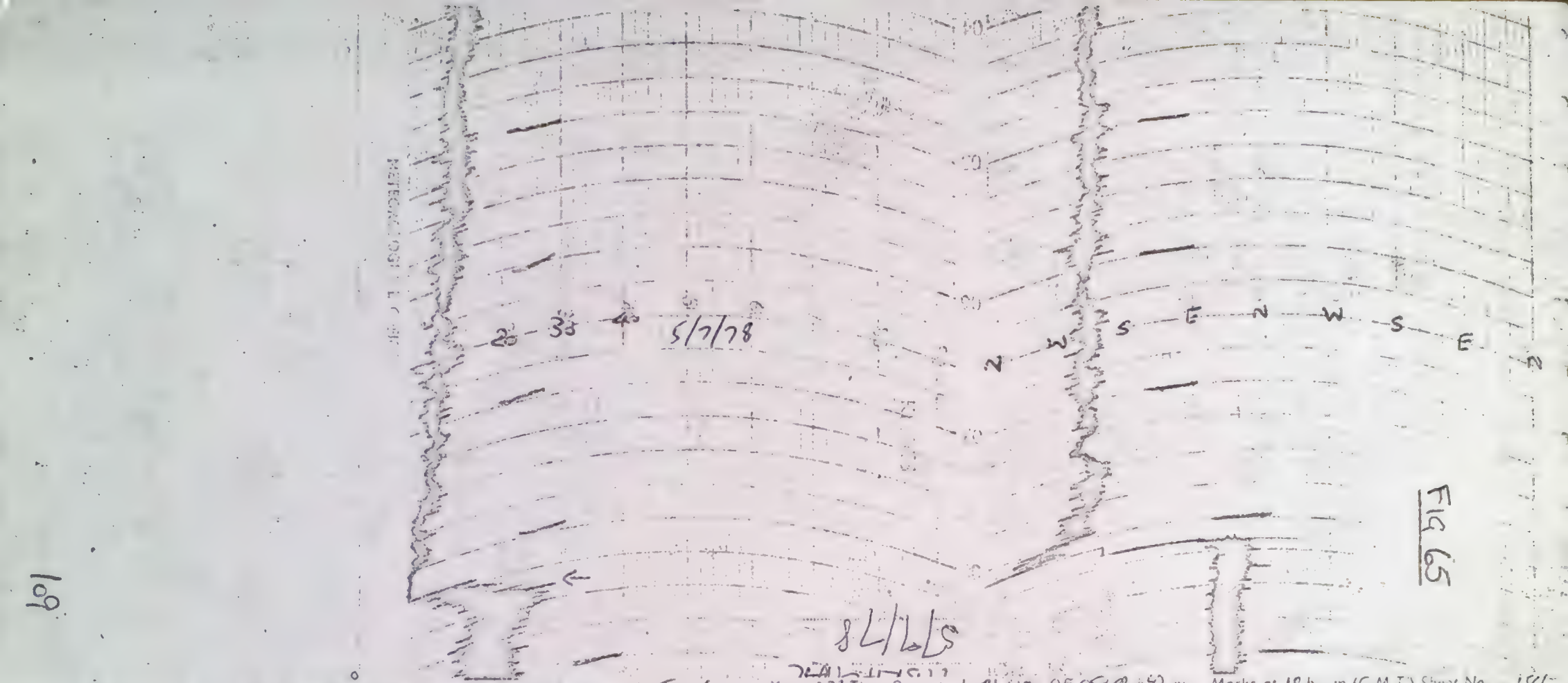
Fig 64

5 JULY 1978 0000Z

31 095 70 11 12	26 111 80 04 12	21 115 32 02 14	24 133 82 00 14	24 144 80 00
4/7/78 18Z	5/7/78 00Z	5/7/78 06Z	5/7/78 08Z	5/7/78 083oZ
22 147 70 32 18 1/09	23 157 58 18 18 4/12			
5/7/78 09Z	5/7/78 10Z			

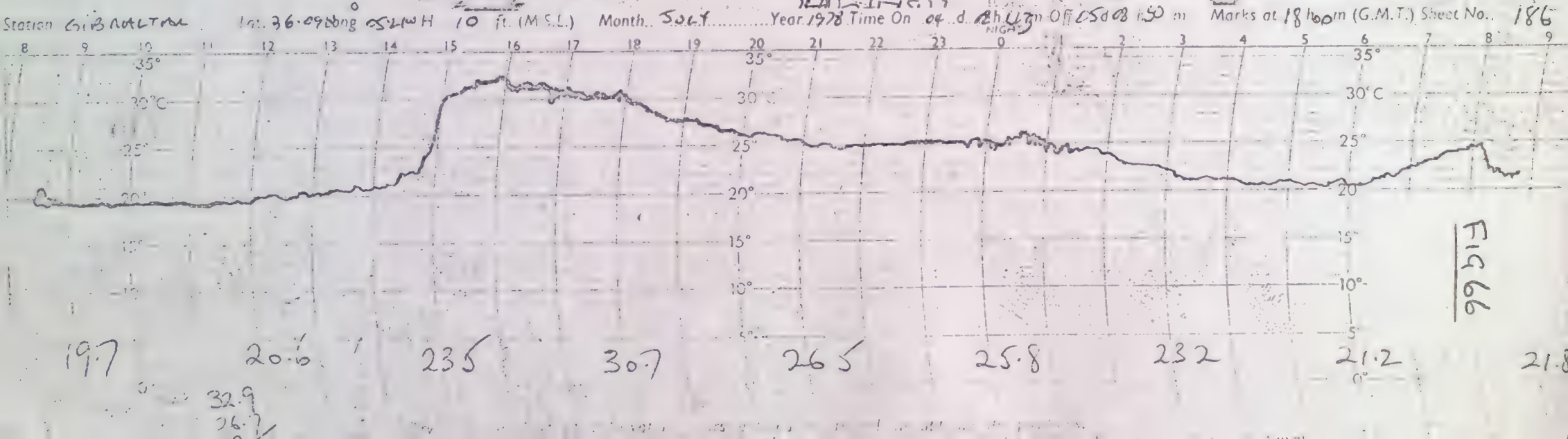
NOTE 7 / A good example of the onset of strong easterlies at Gibraltar in the summer months as a result of a cold front passing south along the eastern coast of Spain and reaching the Alboran Basin. As soon as the front reaches Cap de Gata there is a surge of cold air into the Alboran Basin and within a very few hours fresh or strong easterlies set in at Gibraltar

In this particular case the cold front cloud be easily traced as it passed south down the eastern Spanish coast, particularly by wind changes at coastal stations and in the Balearic islands. The warning signs were the onset of fresh northeasterlies at Ibiza and fresh or strong easterlies at Almeria and Alicante. Frequently there will be no clouds or weather associated with the front but careful note should also be taken of dew point changes and 850mb. isotherms.



5/7/78
N W S E N W S E N

FIG 65



Station GIBRALTAR
Month JULY
Year 1978
Marks at 18 h 00 m (G.M.T.)
Sheet No. 186
19.7
20.6
23.5
30.7
26.5
25.8
23.2
21.2
21.8
32.9
26.7

FIG 66

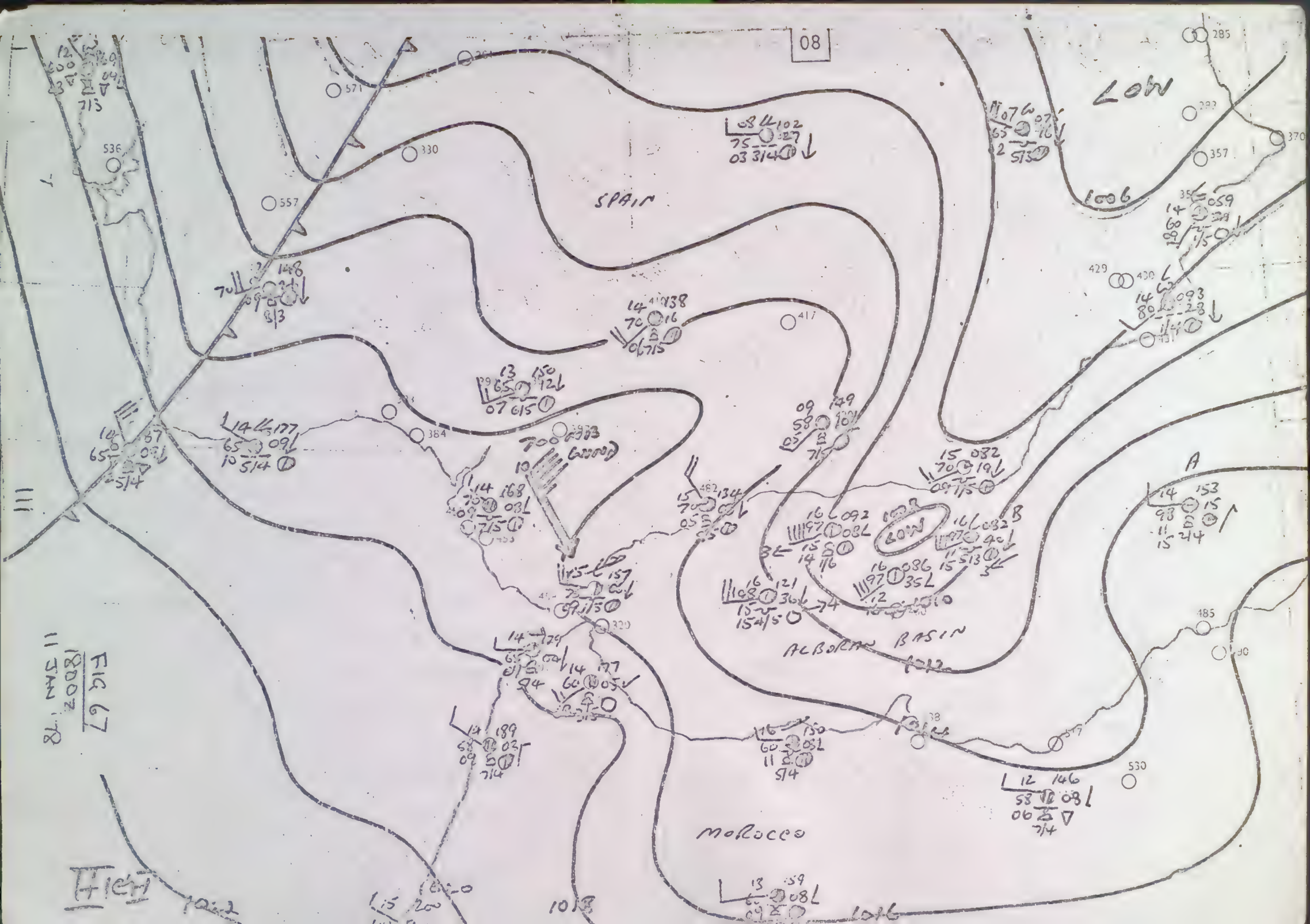
The examples at Figs 67 and 68 show the importance of topography in determining the pressure distribution in the Alboran Basin.

In Fig 67 the flow at the 850-700 mb level is northwesterly, reaching 45 kn at 700mb. Marked cyclogenesis is evident in the Alboran Basin with a well marked trough extending northwards along the coast of Spain. Of particular interest is the change from 10 kn westerlies at Ship A to 40 kn westerlies at Ship B .

In the example at Fig 68 marked cyclogenesis has again occurred in the Alboran Basin as a result of a strong ESE'ly flow over the Algerian mountains, giving rise to gale force winds around Alboran Island whilst some 60 nm. to the northwest a ship is reporting light southeasterly winds.

At Fig 69 is an example of the major part of the Ali-Cas pressure difference concentrated in the Straits area - the situation which gives rise to strong gales to the west of the Straits and severe low-level turbulence over Tangier Bay.

The example at Fig 70 shows a CONTRASTE situation with cyclogenesis in the Alboran Basin which results in the easterlies at Gibraltar being considerably lighter than might have otherwise been expected.


08
LOW
SPAIN
ALBORAN BASIN
MOROCCO
LOW
A
B
1006
1012
1016
1018
1020
700 MB GUND
FIG 67
18002
11 JAN 78

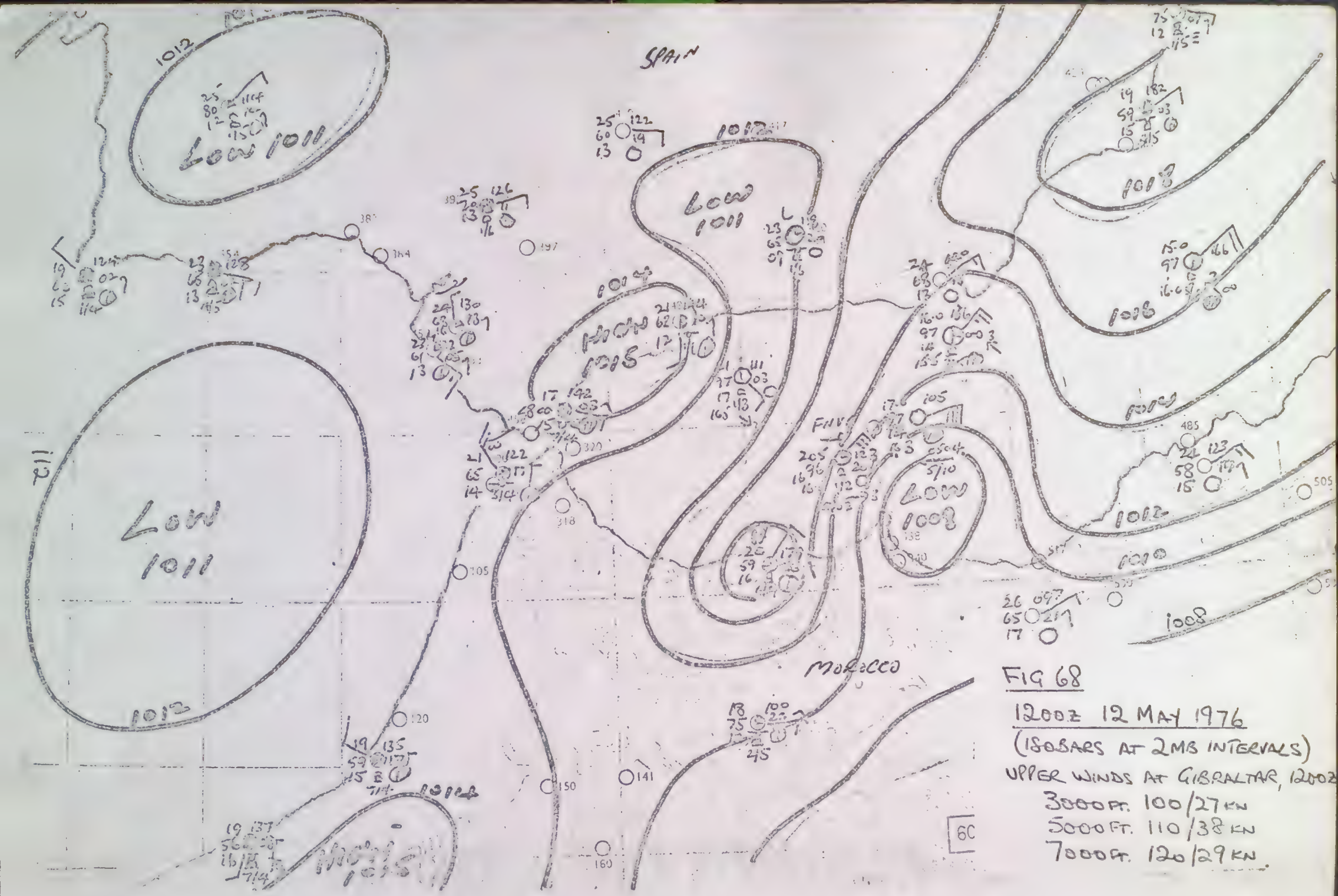


FIG 68

1200Z 12 MAY 1976

(ISOBARS AT 2MB INTERVALS)

UPPER WINDS AT GIBRALTAR, 1200Z

3000 FT. 100/27 KN

5000 FT. 110/38 KN

7000 FT. 120/29 KN

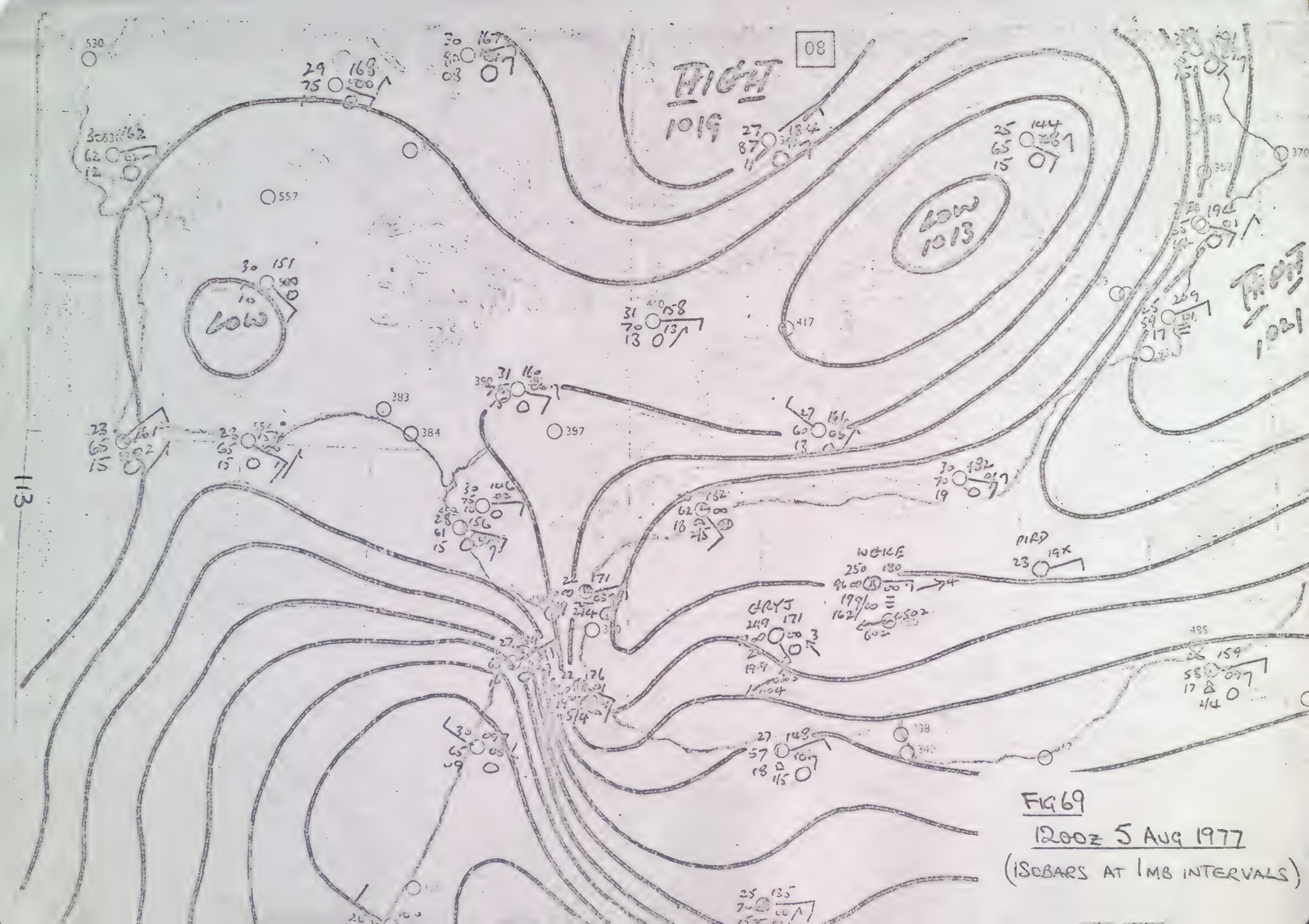


FIG 69

1200z 5 AUG 1977

(ISOBARS AT 1MB INTERVALS)

FIG 7o

12OOZ 29 DEC 1976

(ISOBARS AT 1MB INTERVALS)

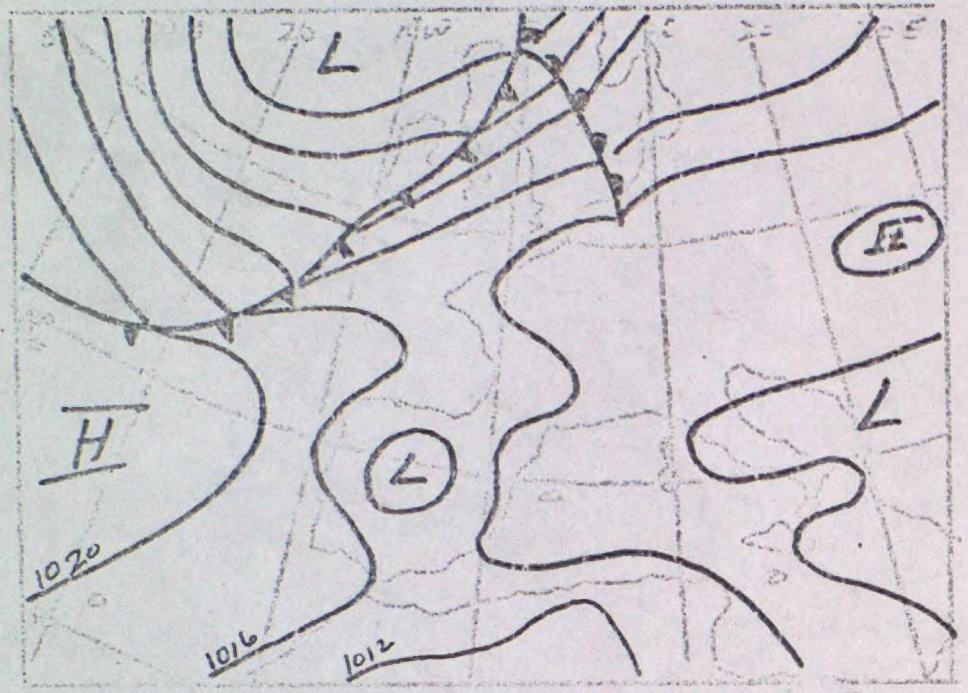


Fig 71 14 AUG 78 12Z

140000Z	140600Z	141200Z	141500Z	141800Z

NOTES:- An interesting sequence showing the onset of thundery activity around Gibraltar with the approach of an upper trough from the west. (See also Figs 73 to 77)

The 700mb flow veered from 210/26 at 131200Z to 240/25 at 14000z as the upper trough retrogressed from 15W to approximately 18W as a fast moving and developing higher latitude trough approached 30W. From 140000z however, the lower latitude trough made a rapid transit eastwards to reach 10W by about 141200Z - a speed of around 35 kts. As the trough moved eastwards the 700mb. flow at Gibraltar backed steadily to 215/26 at 140600Z and 210/17 at 141200Z, and dense Ci and developing Ac Cast appeared. By 141200Z the Ac Cast had developed into high level Cb with a base about 6000 ft. and thunderstorms broke out early in the afternoon both east and west of Gibraltar. The upper trough continued to move rapidly east and at 150000z was located at about 2W. With the passage of the trough over the station , the surface easterlies gave way to westerlies at 142200Z and the high and medium level cloud cleared to give cloudless conditions.

The upper soundings at Gibraltar at 14000Z and 141200Z are worthy of note (Fig 77). They are typical of a summer Southerly flow at Gibraltar with a dry or near dry adiabatic lapse rate in the middle layers. With daytime temperatures reaching 30C or more even at 6000-8000 ft. on the southern slopes of the Riff and High Atlas. Ac Cast is a common evening and nocturnal feature, in this instance a dominant feature was the rapid approach of the upper trough which brought the thundery conditions much earlier in the day than usual.

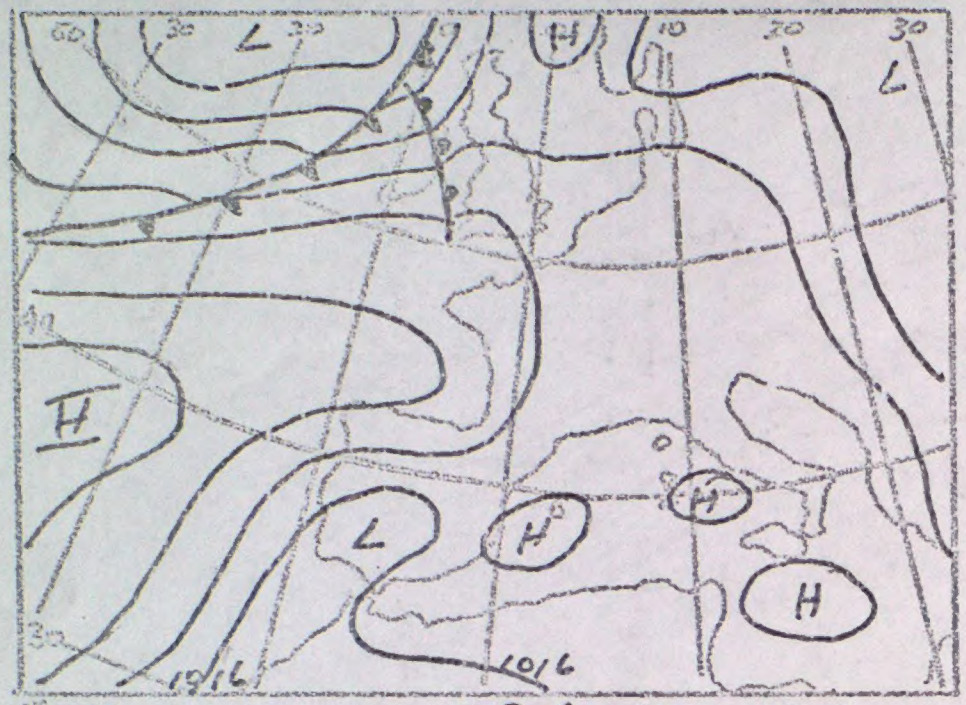


Fig 73 13 Aug 78 12Z

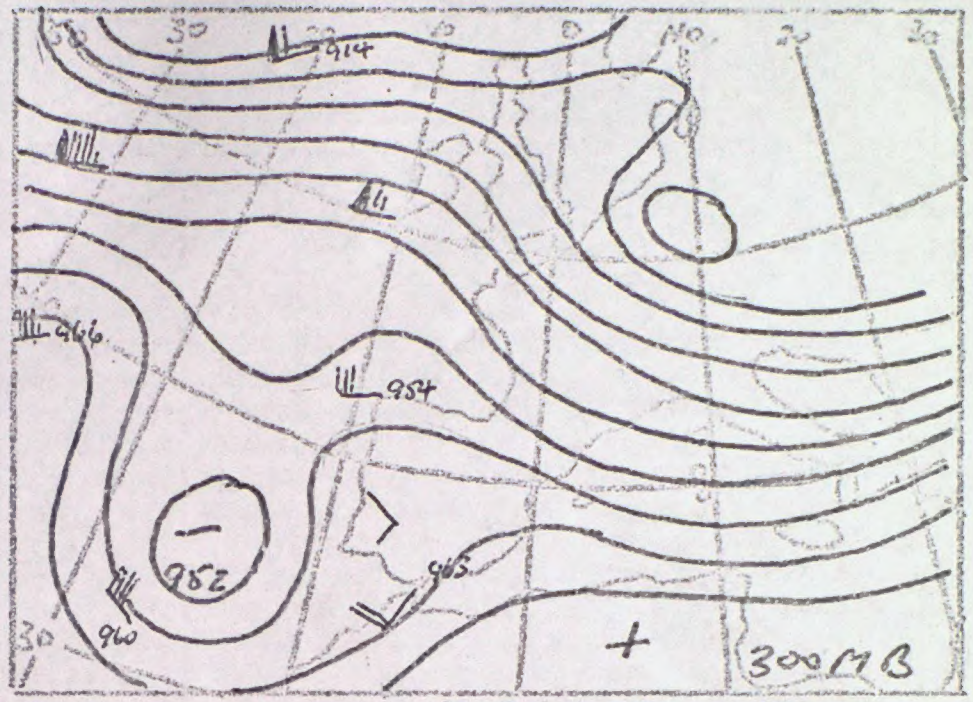


Fig 74 13 Aug 78 12Z

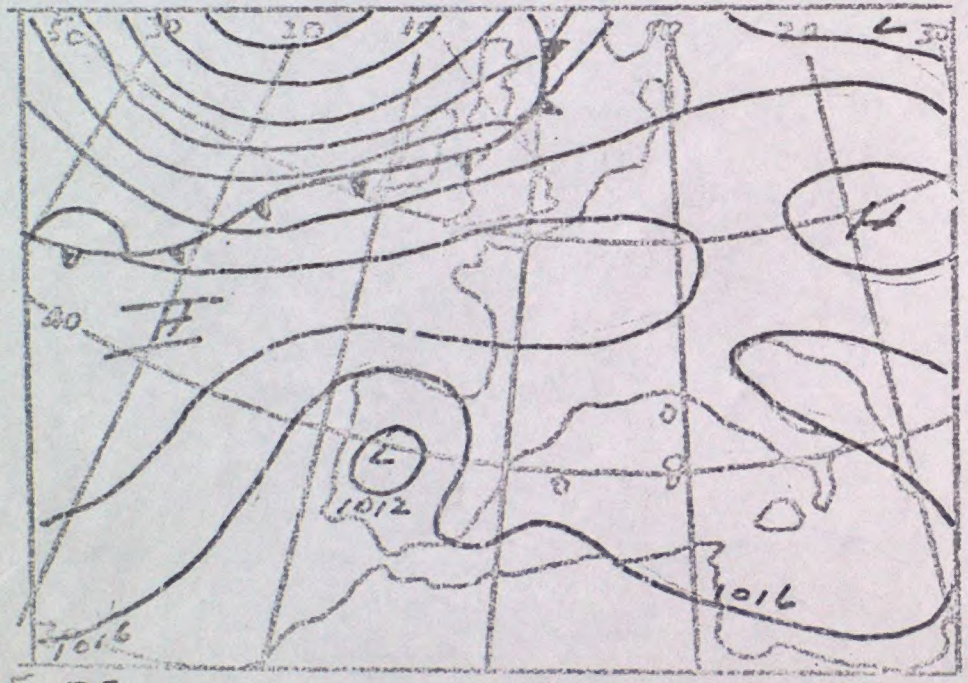


Fig 75 14 Aug 78 00Z

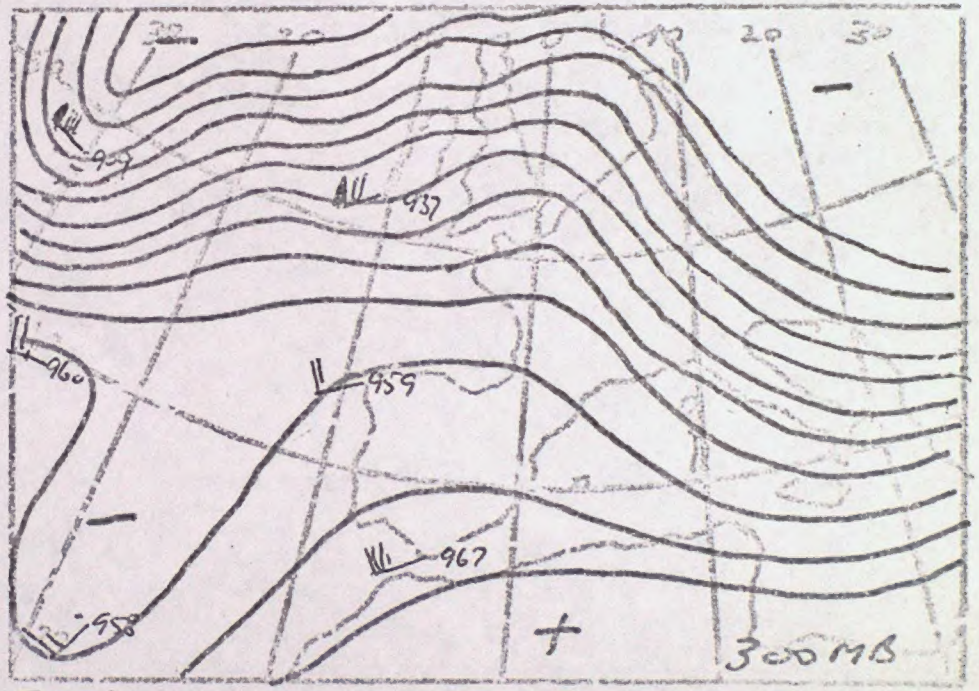
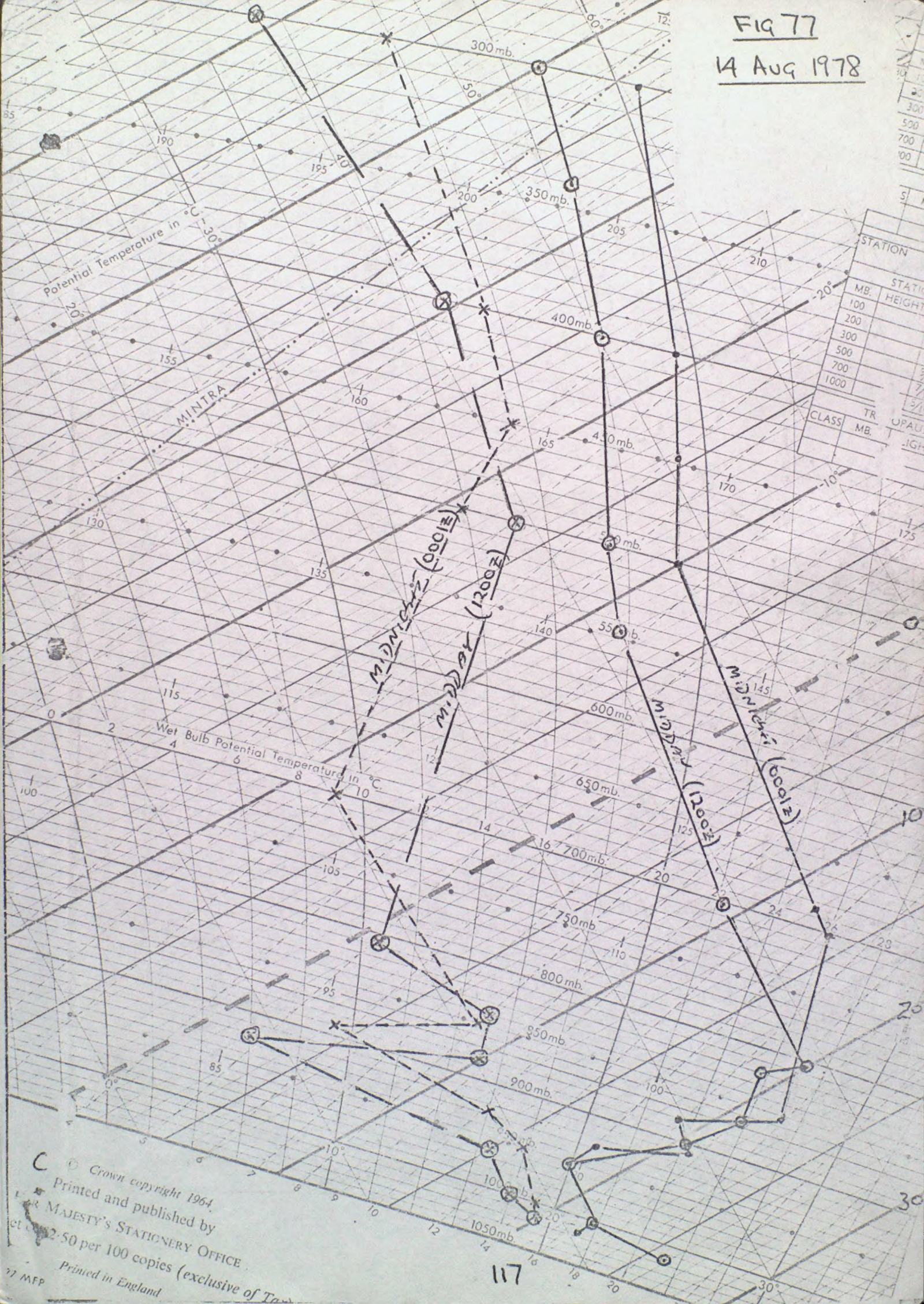


Fig 76 14 Aug 78 00Z



© Crown copyright 1964
Printed and published by
HER MAJESTY'S STATIONERY OFFICE
Price 2·50 per 100 copies (exclusive of Tax)
Printed in England